X-RAYS AND RADIUM

IN THE TREATMENT OF

DISEASES OF THE SKIN

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THE LATE

PROFESSOR JOHN ADDISON FORDYCE

PREFACE TO THE FOURTH EDITION

As a rule, in most vocations and avocations, knowledge and accomplishment advance with each generation. Certainly, this is true of the science and art of medicine of which dermatology is a part. As a result of increased knowledge, together with improved undergraduate and graduate medical instruction, greater facilities and stricter requirements, the modern dermatologist knows more about etiology and therapy than did his predecessors. He is more efficient, his ability and knowledge are much more comprehensive. Formerly he was essentially an externist, now he is both an externist and an internist. He is thoroughly acquainted with the external causes of skin diseases, also with the external management of such diseases, and he knows more about the constitutional causes of the dermatoses than do physicians in any other field of medicine. As Highman once said, it is the dermatologist who knows when to be an externist and when to be an internist.

The foregoing paragraph is a preamble for the statement that x-rays are now employed less frequently in dermatology, and it is possible that they will be used still less frequently in the future. Dermatologists whose training has been inadequate are likely to use x-rays indiscriminately. On the whole, however, there is an increasing disposition on the part of dermatologists to employ x-rays only when necessary or when definitely indicated; in other words, with discriminating judgment. This trend is most noticeable among the older dermatologists and is the result of accumulated experience, also among well trained young dermatologists who are capable of guidance.

Thirty years ago certain dermatoses were treated with x-rays because there was no other equally efficacious remedy. Since then other methods of treatment have proved equal to or superior to x-rays in these particular diseases. For instance, warts of various kinds will often respond more favorably to injections of bismuth or arsenic, or vaccine, or to some other agent than to x-rays. At one time x-rays constituted the therapeutic method of election for the troublesome plantar wart. Now we know that with amounts that can be safely administered only about 70 per cent can be cured in this manner, while it is possible to cure a higher percentage with properly applied electrosurgery. Roentgen rays are of value for selected cases of warts and keratoses but they are by no means always the best or the most certain method.

For a number of years, long ago, the senior author did not fail to cure a case of lichen planus with roentgen rays, therefore, they were supposed to be almost a specific, at least they were considered the method of election. Now it is known that x-rays frequently fail to

cure, and in some instances they do not even modify, the course of the disease. Today we know that many cases of acne vulgaris, eczema, and many other dermatoses respond better to conventional dermatologic investigation and therapy than they do to roentgen therapy alone, and, in any event, it has become the custom, when employing *x*-rays, to use also other established methods instead of depending solely upon irradiation.

Over thirty-five years ago Dr. William Allen Pusey, one of the pioneers of cutaneous roentgen therapy, remarked: "It is hardly too much to say that roentgen therapy is the most widely useful addition to the treatment of skin diseases that has been made." In spite of the foregoing paragraphs and the remarkable advance in dermatology during the past two decades, *x*-rays still constitute the most important single therapeutic agent in the armamentarium of the dermatologist.

It seems advisable to interject here a note of warning. Some dermatologists are still placing too much reliance on roentgen therapy Such an attitude is inimical to the future of the specialty. The essential requisite is an adequate training in every phase of cutaneous medicine, of which roentgen therapy is but a part Such a training should include a thorough knowledge and use of the basic medical sciences, laboratory methods, cutaneous diagnosis and therapy, syphilology, physical therapy, etc Without a training of this kind the dermatologist cannot be resourceful in diagnosis, therapy and research, nor can he use *x*-rays and radium intelligently

Unfortunately, *x*-rays and radium are dangerous agents in unskilled hands. Every physician who employs these agents should have a thorough training in their use, in addition to a general medical training If used for the treatment of skin diseases, the physician who gives or supervises the treatment should be a capable dermatologist and dermatoradiologist. He should, also, possess modern knowledge and adequate equipment

There is today fairly exact knowledge of the nature, biologic action, therapeutic effect and technic of *x*-rays and radium, and the physician should acquire this knowledge before attempting to employ these agents for the relief of human ailments. In spite of this knowledge many physicians are not sufficiently cautious or conservative. Quantities of radiation are being administered to benign lesions and eruptions that are beyond the recommended dose and beyond the limit of safety. Consequently there are entirely too many cases of chronic *x*-ray and radium dermatitis.

In this book an attempt has been made to correlate the specialized knowledge of the dermatologist and radiologist; and to include the essential elements of physics and biology. The last-mentioned material is not irrelevant. Too many physicians use *x*-rays and radium with less knowledge of these agents than that possessed by a well-trained technician who has an M.S. or an M.A. degree.

Considerable attention has been devoted to the historical aspect. *This is deemed advisable because modern skill could not exist without* the efforts of predecessors in the same field of endeavor. The young roentgenologist of today knows little of the difficulties, technical and professional, encountered and overcome by the older roentgenologists, *nor does he appreciate how much is owed to the roentgenologists of* the past, many of whom lost their lives in an endeavor to advance the science and art of roentgenology. These men possessed the pioneer spirit to succeed and the spirit of service. Their work is an inspiration, *their names should not be forgotten.* Furthermore, a knowledge of the more important historical features of roentgenology tends to prevent erroneous claims of originality, it encourages credit for literary priority and it tends to develop a becoming degree of humility.

In the last edition there were a number of collaborators who helped revise the various chapters, all of whom have unselfishly permitted the use of any of their material we have desired to use. We express our appreciation, particularly, to Edith H. Quimby, Sc.D., Associate Professor of Radiology (Physics), College of Physicians and Surgeons, Columbia University, for invaluable aid in preparing the chapters on physics. We acknowledge help received some years ago from the late Harold Bouton, LL.B., when writing the original medicolegal chapter. We thank Dr. Arthur Desjardins, Dr. Franklin H. Grauer, Dr. George M. Lewis and Dr. Fred Wise, for reasons mentioned above. We thank Dr. Arthur Mutscheller for invaluable help with the chapters on physics, biology and technic. We are indebted to Elizabeth S. Margulis, B.S., Librarian, New York Post-Graduate Medical School, and Literary Secretary to the Department of Dermatology, for help with the proof reading and indexing. We are indebted to Dr. Willard C. Rappleye, Dean of the College of Physicians and Surgeons and Director of the New York Post-Graduate Medical School, Columbia University, and to the Post-Graduate Medical Board, for unusual opportunities through a completely self-sustained Department of Dermatology.

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G. M. M.
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New York City

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CHAPTER I

HISTORICAL

ROENTGEN RAYS

The *x* rays were discovered in November 1895 by William Conrad Roentgen Professor of Physics at the Royal University of Wurzburg The discovery was not an accident but the result of previous scientific investigations relative to the curious behavior of high-potential electricity in a rarefied atmosphere

The investigation possibly began with the work of the Abbe Nollet in the eighteenth century He passed a current of high potential through a glass bulb at normal air pressure The current jumped across the terminals as a stream of sparks The air pressure in the tube was then lessened and it was found that as the pressure became less, the stream of sparks broadened out and finally became a luminous band

In 1859 the subsequently well-known Geissler tube was constructed With this crude low-vacuum tube Geissler was able to change the current from a string of sparks into a delicate glow Hittorf, about a year later demonstrated that the Geissler luminous stream could be *deflected with a magnet* This was an important finding and it undoubtedly had considerable influence on the subsequent work of Crookes, Hertz Lenard, and Roentgen

Passing the important observations and experiments of Abria, Faraday Gassiot Spottiswoode, Fernet Goldstein and others, we come to the work of the English physicist Sir William Crookes Crookes devised a pear-shaped tube with a flat, metal cathode at the small end and a metal anode at one side The large end of the tube acted as anticathode This tube was exhausted to a much lower pressure than had been previously obtained Crookes found that the large end of the tube fluoresced a greenish color, that the radiation between the cathode and anticathode could be intercepted by placing suitable metal discs in the tube and that the radiation could be deflected by the magnet as had been previously done by Hittorf Finally he was able to focus the luminous stream on the glass wall at the large end of

the tube by employing a concave cathode. In this way he obtained a more brilliant fluorescence and it was noted that the area upon which the stream was focused became hot. As a result of these and other experiments, Crookes maintained that the luminous stream of Geissler and Hittorf was composed of minute particles, to this stream he gave the name cathode rays.

The work of Crookes excited a great deal of interest and many eminent physicists began to study the cathode stream. In 1892 Hertz placed discs composed of various substances in the path of the cathode stream. In this way he determined that the cathode rays would penetrate a very thin piece of aluminum foil. In order to study the cathode rays outside the tube, Lenard, who had been working with Hertz, sealed a piece of aluminum foil in the large end of a Crookes' tube. He at once determined that the radiation passing through or from the aluminum window was able to penetrate substances that were opaque to ordinary light and after passing through such substances it was capable of causing a fluorescence of the platinocyanide of barium. Furthermore, he noted that this filtered radiation was capable of affecting a photographic plate in much the same manner as ordinary light.

Lenard was under the impression that all the phenomena observed by him were due to the cathode rays, but there can be little doubt that Lenard, Hertz and other investigators had actually produced and observed x-rays but had failed to recognize or isolate them. This great feat was left to Roentgen As a matter of fact, several physicists were investigating the mysterious fogging of light-protected photographic plates in their laboratories when Roentgen's discovery was announced. Roentgen lived to observe the remarkable evolution of roentgenology and superficial and deep roentgen therapy He died in Munich, March 10, 1923, at the age of seventy-seven years

In the latter part of 1895 Roentgen was actuating an ordinary Crookes' tube with a concave cathode, which he had enclosed in a cardboard box, when he noticed that some crystals of platinocyanide of barium, lying at some distance, fluoresced. He then placed various objects between the source of radiation and the barium salt and soon ascertained that the mysterious, invisible radiation would penetrate any material in accordance, roughly, with its density. He determined (erroneously) that the radiation could not be refracted, reflected or deflected. It was obvious to Roentgen that this radiation was not the same as the cathode rays of Crookes, Hertz and Lenard. After ascertaining that the new radiation was developed on the glass wall of the tube at the point of contact with the cathode rays, he endeavored to determine the exact nature of the new radiation, failing in which he modestly termed it the x-rays, presumably on account of the significance of the letter X in mathematical formulæ. By suitably protecting photographic plates from ordinary light, Roentgen was able to obtain shadowgraphs of various opaque objects, including an image of his own

hand with a silhouette of the bones. This was really the birth of roentgenography. At the same time he coated a piece of cardboard with an emulsion of barium platinocyanide and used it as a fluorescing screen or fluoroscope—the birth of fluoroscopy.

Roentgen communicated his great discovery to the world through the medium of the Physico-Medical Society of Wurzburg in December 1895. The communication was at once published in every civilized country and the news was received with astonishment, interest and delight. Physicists, electrical engineers and practical physicians immediately began to experiment and investigate. The power of electric generators was increased, induction coils were wonderfully improved as, also, were static machines. But Mr Herbert Jackson made what was probably the greatest single step of the time in the way of a practical addition to the necessary apparatus. Making use of Crookes' discovery that the cathode stream could be focused and intercepted, he focused the cathode rays on a platinum disc placed within the tube, thus creating the first real focus tube. In an incredibly short time x-ray operators were making routine examinations for fractures, dislocations and foreign bodies.

During this practical work and scientific investigation several experimenters noticed that after a prolonged exposure to x-rays an erythema of the skin was produced and in some instances a dermatitis and even deep ulceration occurred. This was recognized as an x-ray reaction. This biologic effect particularly attracted the interest of Schiff and Freund and it was only a month or two after Roentgen's announcement that they suggested the use of the x-rays in the treatment of disease. This was the birth of roentgentherapy. The first therapeutic attempts were made in nevus, hypertrichosis, cancer and tuberculosis.

Within a few months the medical press was literally swamped with accounts of the more or less successful treatment of various diseases with the x-rays. At first enthusiasm and carelessness overcame caution. Many physicians installed apparatus and attempted to employ the x-rays for practical therapeutic purposes without making a study of the subject. Even the scientific and conscientious workers did not at first realize that they were dealing with an exceedingly dangerous agent. It was natural, therefore, that many patients received serious injuries. Not only were patients injured but operators by repeatedly testing the penetrating power of the rays by inserting their hands between the tube and a fluorescing screen developed an erythema which in many instances led to serious sequelæ. In a book entitled American Martyrs to Science (Charles C Thomas, 1936) Percy Brown has written a glorious and pathetic account of the sacrifices made by many of the American pioneers in this field. These facts together with the discovery by Brown and Osgood that sterility was produced by the x-rays naturally caused operators to be a little more cautious. However optimism reigned until about 1906. During those years the rays, to a large extent, were empirically used and

they were tried out on nearly every chronic disease. The literature was misleading, as it was full of case reports of wonderful cures; the occasional paper from the pen of a good man was ignored or overlooked by the average x-ray operator of the period, and, in spite of repeated warnings from capable men, the "radiomaniacs" held the reins.

It was soon found that the x-rays were capable of producing a cure in only a certain percentage of cases of the basal-cell type of cutaneous epithelioma, that they were exceedingly unreliable in malignant cancer and that, in any event, they did not replace surgery. This was a keen disappointment. The x-rays proved practically useless in pulmonary tuberculosis. This was another great disappointment. Finally, the lay public and even the greater part of the medical profession not only lost faith in the therapeutic value of the x-rays, but considered them an exceedingly dangerous agent. The unverified accounts of marvelous results, the injurious effects observed as time went on, the fact that there was no satisfactory method of estimating the amount of radiation administered, and the fact that the earlier claims were not substantiated, finally resulted in a period of pessimism which lasted from about 1906 to about 1912.

During this period there were a number of scientifically inclined roentgenologists who recognized both the advantages and limitations of the x-rays and who also recognized the necessity of standardizing the work and of devising accurate methods of measurement.

Among the first roentgen therapeutists in this country were Pusey, Allen, Piffard, Stelwagon, Pancoast, Williams and others In Europe the illustrious early therapeutists were Schiff, Freund, Béclère, Brocq, Belot, Schonberg, Hall-Edwards, Heinecke, Holzknecht, Kienbock, Schmidt, Benoist, Walker, Oudin, Barthélémy, Walsh, Morris, Sequeira, and others.

For a number of years the greatest interest was associated with the development of new exciting apparatus and instruments of precision or of measurement. In this country the static machine reached perfection. Some even went so far as to build vertical machines possessing fifty or more plates. Improvements in the Ruhmkorff coil, however, soon caused this apparatus to displace the static machine, and the coil was used almost exclusively until the advent of the interrupterless transformer, which was placed on the market by Snook, of Philadelphia, in 1908 This machine, by doing away with the troublesome interrupter, and by providing a reliable and easily controlled unidirectional current of great strength, proved to be one of the big additions to roentgenology.

Numerous methods and instruments were devised for the purpose of estimating the quality or penetrating power of the x-rays. One of the first instruments for the purpose was the spintherometer of Béclère which was simply a calibrated, adjustable, parallel spark gap. Benoist, in 1901, produced his radiochromometer. Then there were many other instru-

ments devised for this purpose (Walter penetrometer, Wehnelt penetrometer, Heinz-Bauer qualimeter, voltmeters, etc.), but the spark gap remained the favorite practical method of measuring quality for many years.

For a number of years it was the custom to estimate the quantity of radiation administered by establishing various constants, such as milliamperage, spark gap, number of interruptions per second, distance of anode from skin, etc. This was an exceedingly difficult thing to do before the advent of the Coolidge tube and the interrupterless transformer, and the method was so uncertain and dangerous that many investigators devoted a great deal of time in an endeavor to perfect some method of direct measurement. Kienbock established the law that "the degree of reaction depends upon the quantity of x-rays absorbed by the skin." Also the law relative to the intensity of the rays being inversely as the square of the distance or directly as the sine of the angle became well established and was of great help to therapeutists. In 1902 Holzknecht presented the first instrument for direct measurement of quantity; this was called the chromoradiometer. It consisted of a capsule containing a liquid of secret formula which changed color when exposed to the x-rays. By employing a graduated color index one could read the dose in units. This method was found unreliable and was discarded for his second instrument, the Holzknecht radiometer.

In the meantime, numerous instruments and methods designed for this purpose made their appearance. Among the most notable was Kienböck's idea of employing strips of standardized photographic developing paper. Then Sabouraud and Noiré developed their radiometer which depended upon the color changes produced by the x-rays in barium platinocyanide. The radiometers of Holzknecht, Bordier, Hampson and Corbett were all modifications of the Sabouraud-Noiré instrument.

In the early days x-ray tubes were a source of great trouble. It was difficult to regulate the vacuum and impossible to maintain it when heavy currents were used, and with heavy currents the anode would melt. Tungsten targets and water-cooled and air-cooled tubes, improved vacuum pumps and vacuum regulators lessened these difficulties considerably. In spite of all the marked improvements in gas tubes, there was no perfectly satisfactory x-ray tube for therapeutic purposes until 1914, when Coolidge announced his electron tube—a discovery that at once revolutionized roentgentherapy.

In this country the electrical or indirect method of quantity estimation was found so satisfactory that the troublesome photographic and pastille methods were discarded. Physicists have always depended upon ionization measurement. Ionization chambers are now being used by practical workers.

In addition to the accomplishments of scientifically inclined physicians and electrical engineers, it must not be forgotten that many

physicists, biologists, chemists, and physiologists persistently investigated the x-rays and radioactive substances from the very moment of their discovery. The work of these men paved the way for most of the improvements in the technic of recent years and, of course, as a result of their tireless endeavors we now possess a fairly reliable conception of the nature of the x-rays and of the radioactive substances.

At last the value and limitations of the x-rays in the treatment of disease have been fairly well established. Improvement in technic, definite knowledge regarding possibilities and limitations, and the fact that radiodermatitis can be avoided, have restored confidence, and this confidence can be permanent if the work can be kept out of the hands of overenthusiastic and careless individuals.

CHAPTER II

HISTORICAL—Continued

THE RADIOACTIVE ELEMENTS

Radium was discovered by Mme Curie in 1898 three years after Roentgen's famous announcement. The result of the research appeared as a joint paper by Prof. and Mme Curie and G. Bemont. Like Roentgen's discovery, the isolation of radium was preceded by pertinent investigations, this time by Becquerel, Mme Curie and others.

As we have seen, there was considerable controversy in 1895 relative to the nature of the cathode rays of Crookes. Finally, in 1897, J. J. Thompson proved definitely that the cathode stream consisted of negatively charged particles moving with great velocity. He determined that these particles were much smaller than the most infinitesimal particle of matter at that time known to scientists, namely, the atom of hydrogen. He concluded that they represented a new state of matter and designated them by the name electrons. It will be recalled that Thompson, Lenard, Crookes and others had called attention to the fluorescence of the glass wall of the tube under the bombardment of the cathode rays. After the discovery of the *x* rays it was conceded that the cathode stream was their parent, and it was erroneously thought that the fluorescence of the glass wall of the tube had some influence in the production of the roentgen rays. With this idea in mind several physicists studied various substances that phosphoresced *under the influence of light. Becquerel for instance, protected a* photographic plate from ordinary light and exposed it to the double sulphate of potassium and uranium. The plate became fogged after a prolonged exposure showing the presence of rays capable of penetrating light opaque material. It was noticed, too, that the same effect was obtained even when the potassium-uranium salt had ceased to phosphoresce. Later, the radiation obtained from pure uranium was shown to possess characteristics similar to those of the *x*-rays. Later still, it was determined, as a result of the work of Becquerel, Curie, Villard and others that uranium emitted three types of radiation, namely alpha, beta and gamma rays.

Immediately after Becquerel's discovery Mme Curie conducted a systematic examination of various substances for evidence of radioactivity and found that the element thorium demonstrated similar properties to those observed in uranium, and to about the same degree. To quote from Rutherford: "An examination was then made of the

natural minerals which contain thorium and uranium and here an unexpected result was observed. Some of these minerals were found to be several times more radioactive than pure uranium or thorium and in all cases the uranium minerals showed four to five times the activity to be expected from the percentage of uranium present. Mme. Curie found that the radioactivity of uranium was an atomic property, *i. e.*, the activity observed depended only on the amount of the element uranium present and was not affected by its combination with other substances. This being so, the large activity of the uranium minerals could only be accounted for by supposing that another substance was present, which was far more active than uranium itself.

"Relying on this hypothesis, Mme. Curie boldly proceeded to see if it were possible to separate chemically this unknown active substance from uranium minerals. By the courtesy of the Austrian Government, she was presented with a ton of uranium residues from the State Manufactory at Joachimsthal, Bohemia. In this locality there are extensive deposits of uranite commonly called pitchblende, which are mined for the uranium they contain. This pitchblende consists mainly of uranium, but also contains small quantities of a number of rare elements.

"As a guide to the separation of the active substance, Mme. Curie employed a suitable electroscope to measure the ionization produced by the active body. After each chemical separation, the activities of the precipitate and of the filtrate evaporated to dryness were separately examined and in this way it was possible to ascertain whether the active substance had been mainly precipitated or left behind in the filtrate.

"The electric method was thus used as a rapid means of qualitative and quantitative analysis. Proceeding in this way, Mme. Curie found that not one but two very active substances were present in the uranium residues. The former of these, which was separated with bismuth, was called polonium, in honor of the country of her birth and the latter, which was separated with barium, was called radium. This latter name was a happy inspiration, for the activity of this substance in a pure state is at least two million times that of uranium."

The development of the theory of ionization of gases by Wilson, Thompson, Rutherford, and Townsend (1896 to 1899), proved of great value in the search for radioactive elements and in the comparative study of the physics of these elements and of the x-rays.

In 1899 and 1900, as a result of the work of Giesel, Becquerel, and Villard, the alpha, beta and gamma rays of radium were separated and studied. The beta rays were shown to be similar to the cathode rays—negatively charged particles traveling at great velocity, deflected by a magnet and possessing considerable penetrating power. The alpha rays were also found to consist of particles having less velocity than those of the beta rays, possessing very little penetration and deflected by a magnet in the opposite direction from the beta rays—

therefore the charge was positive instead of negative These rays were later shown to be similar to the canal rays of the x-ray tube

The gamma rays were found to be very similar to the x-rays in that they were very penetrating, they produced the same ions as the x-rays and like the latter, the gamma rays could not be deflected, reflected nor refracted by any means known at the time

At about this time Rutherford showed that thorium emitted a gaseous radioactive substance which was called an emanation Then Mme Curie demonstrated that all bodies placed in the immediate neighborhood of radium became temporarily active This induced activity was caused by the deposit from the radium emanation, now known as radon

In 1902 Rutherford and Soddy demonstrated that a very active substance, called thorium X, could be separated from thorium The new substance would lose its activity in time while the thorium, freed from thorium X, would spontaneously produce a new supply It was determined that thorium emanation was derived from thorium X and not directly from thorium Knowing that the radioactive property of an element was atomic and, therefore, that the alteration must occur in the atom and not in the molecule Rutherford and Soddy advanced their well known disintegration theory

Radium therapy began with the famous "Becquerel burn" In 1901 Becquerel placed a tube of radium in the pocket of his waistcoat where it remained for several hours A week or two afterward a severe inflammation appeared in the skin underneath the radium Besnier examined this dermatitis and expressed the belief that it was due to the radium Walkoff avers that he reported a case of radium dermatitis in 1900 and, therefore, claims priority Prof Curie then made some experiments on his own person and conclusively proved that the radiation was capable of effecting an inflammatory reaction in normal skin Being cognizant of the early results of roentgentherapy and familiar with the *inflammatory reactions obtained* by Becquerel and Curie Besnier suggested the use of radium as a therapeutic agent For this purpose Becquerel loaned some radium to Danlos of the Hopital St Louis, where it was soon found that the new agent exerted a beneficial effect on a number of diseases Danlos' work was continued by Masotti and the results were published by the latter in book form at a later date

The pioneers in Europe were Lazarus Mache Szilard Danlos, Wickham and Degrais Bashford Becquerel, Czerny, Freund Bayet Schiff and others In this country Abbe, of New York, was probably the first physician to employ radium for practical purposes

Radium therapy developed more slowly than did roentgentherapy, largely because the substance was expensive and difficult to obtain About thirty years ago this branch of the medical science received a great stimulus through the repeated announcements that large quantities of radium would cure cancer The propaganda while

harmful at the time, really accomplished considerable good, as it encouraged several institutions to purchase large amounts of the element which were placed under the control of scientific and conscientious observers In consequence, the true value of radium in the treatment of cancer has been determined.

BIBLIOGRAPHY

ALLEN, C W Radiotherapy and Phototherapy, Including Radium and High-Frequency Currents, Philadelphia, Lea & Febiger, 1904

BELOT, J. Radiotherapy in Skin Diseases, New York, Rebman Company, 1905

CURIE, M Pierre Curie, Paris, Payot, 1924, New York, The Macmillan Company, 1923

FREUND, LEOPOLD Ein mit Röntgen-Strahlen behandelter Fall von Nevus pigmentosus piliferus Wien med Wchnschr, 47, 427, 1897

GLASSER, OTTO, ed The Science of Radiology, Springfield, Charles C Thomas, 1933.

——— Wilhelm Conrad Röntgen and the Early History of the Roentgen Rays, Berlin, Julius Springer, 1931, London, Bale, 1933, Springfield, Charles C Thomas, 1933.

KIENBÖCK, ROBERT On the Quantimeter Method, Arch. Roentg Ray, 11, 17, 1906–07

——— Ueber Radiotherapie der Haarerkrankungen, Arch f Dermat u Syph, 83, 77, 1907.

LAZARUS, P. Handbuch der Radium-biologie und Therapie, Wiesbaden, J F Bergmann, 1913

MASOTTI Traitement des dermatoses par le radium, Paris, J B Baillière et fils, 1910

NEWCOMET, W S Radium and Radiotherapy, Philadelphia, Lea & Febiger, 1914

PUSEY, W A. Principles and Practice of Dermatology, New York, D Appleton & Co, 1907

PUSEY, W A, and CALDWELL, E W. The Practical Application of Roentgen Rays in Therapeutics and Diagnosis, Philadelphia, W B Saunders Company, 1904

RUTHERFORD, E Radioactive Transformations, New York, Scribner's, 1906

SABOURAUD R and NOIRÉ, H Traitement des teignes tondantes par les rayons X á l'École Lallier, Presse méd, 2, 825, 1904

SCHULTZ, FRANK Die Roentgentherapie in der Dermatologie, Berlin, Julius Springer, 1910.

WICKHAM, L F., and DEGRAIS, PAUL Radiumtherapy, London, Cassell & Co, 1910

WILLIAMS, F. H. The Roentgen Rays in Medicine and Surgery 2d ed, New York, The Macmillan Company, 1903

CHAPTER III

THE STRUCTURE OF MATTER AND THE NATURE OF RADIATION AND OF ELECTRICITY *

THE STRUCTURE OF MATTER

Roentgen rays and the radioactive elements are valuable agents not only in the diagnosis and treatment of disease but also in many industries. They are also valuable in studying the structure of matter. It was formerly believed that all atoms were indivisible and represented the smallest particle of an element. Now the conception is radically different.

Atom.—All elements, of which there are 94, are made up of atoms. They may be likened to minute solar systems. The simplest is that of hydrogen which, in its standard form, consists of a central nucleus with one particle traveling in an orbit around it. Practically all of the mass is concentrated in the nucleus, which has associated with it one positive electric charge. The satellite is an electron, which is the element of negative electric charge. The complete atom is, therefore, electrically neutral, the electron's negative charge just balancing the positive charge of the nucleus. Such an atom is depicted in Fig. 1 *A*.

Electron.—An electron is considered as actually a particle of electricity with a negative charge; when at rest or in not too rapid motion it has an effective mass about $\frac{1}{1850}$ that of the hydrogen nucleus.

Proton.—The hydrogen nucleus is the smallest particle of matter. It therefore occupies position No. 1 in the atomic scale. The nucleus, without its electron and with its unit positive charge, is called a *proton*; it is one of the fundamental building blocks of matter.

Neutron.—The next atom in order of simplicity has a nucleus twice as heavy as that of hydrogen just described, but still a single net positive charge and a single orbital electron. This nucleus contains two protons and one electron. There is still one electron in the orbit; one proton and one electron neutralize each other electrically. In fact, this pair of particles is supposed to exist in very close combination and as such is called a *neutron*. A neutron thus has practically the weight of a proton but no electric charge. It is also one of the fundamental particles. The atom just described, and shown diagrammatically in Fig. 1 *B*, is that of deuterium, or "heavy hydrogen." The characteristic which it has in common with ordinary hydrogen is the net single charge on the nucleus and the single orbital electron.

Helium Atom.—This has a nucleus consisting of two protons and two neutrons; it has, therefore, a mass of 4 and a nuclear charge of 2, and requires two orbital electrons to make it electrically neutral.

* In the last edition this chapter was revised by Dr. Edith H. Quimby. Some of the material added by Dr. Quimby has been retained in this edition.

This nucleus, without the satellites, is another of the structural units It is called, for reasons which will be apparent later, the *alpha particle* The diagram of this atom is given in Fig. 2.

It is not necessary to go into detail regarding the building up of more atoms. From this point on, no new fundamental particle appears. All atoms seem to be composed of protons, neutrons, and alpha particles, combined with electrons.

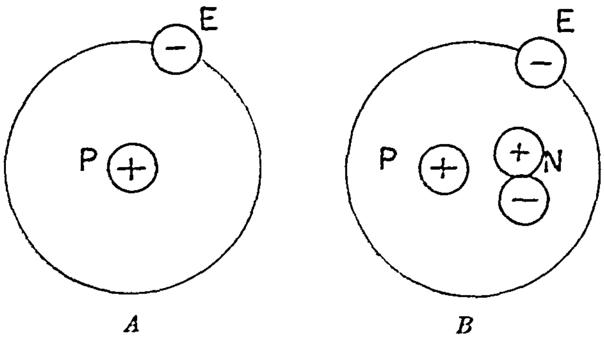

FIG 1 —The atomic structure of hydrogen *A*, ordinary hydrogen, *B*, deuterium

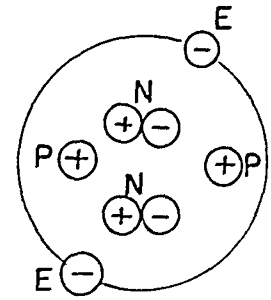

FIG 2 —The atomic structure of helium

RADIATION.

The term *radiation* has come to include two quite different concepts Under various stimuli, external or internal, atoms may break down with the violent ejection of electrons, neutrons, or protons. These particles may be spoken of as various types of radiation It is also possible to set such particles in rapid motion by the action of high voltages, resulting in the so-called positive rays and cathode rays.

The second kind of radiation is that known under the general heading of *electromagnetic waves*. When, for any reason, and by any means, an electron is accelerated or decelerated, such waves are generated. They spread out in all directions from the source, traveling in a hypothetical medium called the ether. These electromagnetic radiations exist in a tremendous range of wave lengths or frequencies,[1] they all travel in a vacuum with the same speed, that of visible light, 186,000 miles per second. Some of these rays produce effects which make them readily perceived by our senses without special apparatus, others require the use of delicate instruments for their detection Most familiar, and occupying an intermediate position in the electromagnetic series of radiations, are the waves of visible light. Ordinary white light, on being passed through a prism, or passed through or reflected from a diffraction grating (a glass or metal plate on which have been ruled many accurately spaced fine lines), is spread out into a spectrum of colors, each having its own distinctive range of wave lengths These wave lengths are measured in Ångström units,

[1] The frequency is the number of waves passing a given point in a second It is therefore, the velocity divided by the wave length

1 Ångstrom being $\frac{1}{100,000,000}$ cm (10^{-8} cm) Longer than the longest visible rays are the heat waves with lengths up to 300,000 Å Of still greater length are the Hertzian waves ranging from a fraction of an inch to several miles Some of these are used in radio broadcasting and in heat production in short-wave diathermy equipment

On the other side of the visible rays are the ultraviolet with wave lengths down to 600 Å Beyond the ultraviolet comes the region of *x*-rays and gamma rays with wave lengths down to less than 0 01 Å (Cosmic rays were at one time thought to be electromagnetic radiation of shorter wave length than gamma rays They have now been shown to be largely if not entirely particle radiation)

Electromagnetic Waves in Tabular Form

Radio waves	0.2 mm to .0+ miles
Infra red	0007 mm to 0.4 mm
Visible light	4000 Å to 7000 Å
Ultraviolet light	40 Å to 4000 Å
X rays	06 Å to 500 Å
Gamma rays	0006 Å to 0.3 Å

A beam of *x*-rays can be separated into various components according to wave length by passing it through a crystal Various methods have been developed for studying the *x* ray spectrum Fig 3 is a diagram of the whole series of electromagnetic radiations

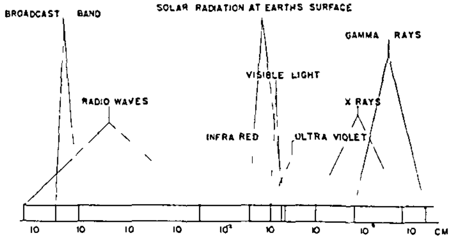

Fig 3 —The electromagnetic spectrum

Photon —Certain aspects of the behavior of these rays are difficult to describe when they are considered as waves this is particularly true of the scattering phenomena which play an important part in the passage of the radiations through matter Under certain circumstances a beam of *x*-rays acts much more like a shower of discrete particles than like a series of waves In fact physicists state that the rays have both a wave aspect and a particle aspect depending on the method used to observe them There is no contradiction in this

neither description is complete and both are necessary. As a matter of fact, most of the phenomena of radiation which are observed in connection with a study of radiation therapy, are much more readily described on the particle, or *quantum* idea. From this point of view a single x-ray, instead of being regarded as a chain of waves, is considered a particle or projectile of pure energy. In this aspect it is called a *photon*. The energy of the photon, or its *quantum*, corresponds to the wave length or frequency of the ray. X-rays of long wave length or low frequency are photons of low energy quanta, those of short wave length or high frequency are photons of high energy quanta; the two descriptions of a particular ray are interchangeable. The terminology of both concepts will accordingly be used in the discussion of the behavior of radiation.

ELECTRICITY.

Electric Charge.—The fundamental concept of electricity is the electric charge. We have already described the electron as the elementary negative electric charge. The elementary positive charge seems to be usually associated with the atomic nuclei.[1] Two like charges, positive or negative, repel each other; two unlike charges attract each other. Matter is, in general, electrically neutral because the normal atom contains equal amounts of positive and negative charge.

Many substances can be charged by friction, some negatively, some positively, some strongly, others only slightly. Among these are glass, rubber, amber and wax; in short, all the substances which we know as *insulators*. Others, including all metals, refuse to acquire a charge of this sort, because in some way the charge is led, or *conducted*, away as fast as it is formed. These substances are called *conductors*.

Electric Force.—Since an electric charge attracts or repels another charged body, it must exert a *force* on it This force may be measured mechanically in the same sense as the force of gravitation. We say, therefore, that an electric *field of force* surrounds a charged body and we may represent it by saying that lines of force go out from the charge, the number of lines being proportional to the strength of the field, or each one representing a unit electric charge. A diagrammatic representation of a charge with its lines of force is shown in Fig. 4

Quantity of Electricity.—The total charge on a body, negative or positive, is spoken of as the quantity of electricity. It can be measured by the force it exerts on another charged body.

Electric Potential.—Since two like charges repel each other, work must be done to bring them together. The closer they are to be placed, the more work must be done. The amount of work necessary to bring a unit charge to a point at a given distance from a given charged body is called the *potential* at the point due to the charge.

[1] An elementary positive charge, the *positron*, has been shown to exist It is not, however, significant in our study.

At a greater distance from the charge the potential will be less The *difference in potential* between the two points represents the amount of work which must be done to bring a unit charge from the lower to the higher

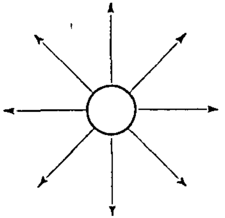

FIG 4 —Field of force around electric charge

Electric Current —If two conductors at different potentials are connected by a third conductor electricity will pass from the higher to the lower until the charges are equalized We say that a *current of electricity* flows through the connecting conductor, just as a current of water flows through a connecting pipe from a tank with a higher level to one of lower, until the levels are the same

Electric current may be carried entirely by electrons, as in the case of conducting solids, or by charged portions of molecules or atoms, as in the case of certain solutions or of liquids and gases under certain conditions

Ionization —1 *Chemical Ionization* —When acids bases or salts are put into dilute solution in water some molecules of the substance break into two parts, one of which is negatively charged, the other positively For example in dilute sulfuric acid, H_2SO_4 some molecules separate into H_2 with two positive charges and SO_4 with two negative The metals and hydrogen always carry the positive charge and the remaining part of the molecule the negative The amount of the charge on either *ion* or charged particle does not depend at all on the nuclear charge of the atoms but only on their valence [1]

This process of breaking down in dilute solution is known as *dissociation* or *ionization* the charged particles are *ions* substances which act in this manner are *electrolytes* If now two conductors at different potentials—*electrodes*—are placed in the solution the negative ions will go to the positive electrode, or *anode,* while the positive ions will go to the negative electrode, or *cathode* This passage of charged particles constitutes an electric current in the liquid Once arrived

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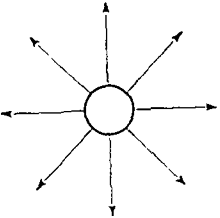

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at the electrodes, the ions give up their charges, either escape into the air (if gaseous), settle upon the electrode (if metallic) or enter into chemical combination with it.

2. *Radio-Ionization.*—The action on gases and liquids of various agents, including heat, ultraviolet light, *x*-rays, and the radiations from radioactive substances, produces an effect which is also called ionization, but which is entirely different from the phenomenon just described in solutions. In the gas or liquid atom or molecule, a single electron is detached.[1] This may remain alone or may attach itself to an intact molecule; with or without an attached particle it constitutes the negative ion. The rest of the damaged atom or molecule, being left with a net positive charge, is the positive ion. As in the case of the solution, positive and negative electrodes introduced into the ionized medium will attract negative and positive ions respectively, and a current will pass through the electric circuit.

Ampere.—The ampere measures the rate of flow of electricity and it is that current which, under specified conditions, deposits 0.001118 gram of silver every second from a silver salt solution.

The quantity of electricity associated with 0.001118 gram of silver ions is called 1 *coulomb*, hence 1 ampere of current is the passage of 1 coulomb per second.

Electric current is measured by ammeters, or if very small, by milliammeters or microammeters

Ohm.—The ohm is the unit of resistance to the flow of current. Different conductors offer different degrees of obstruction to the flow of electricity. One ohm is the resistance offered to a constant electric current by a column of mercury at 0° C., 14.4521 grams in mass, of a uniform cross-section, and of a length of 106.3 cm.

Potential Difference; Electromotive Force; Voltage—The term difference of potential has been explained above. Electromotive force (E.M.F.) is a term given to any cause, whatever its nature, which is capable of producing a difference of potential. It is, therefore, measured in the same units as difference of potential, and is, in fact, frequently confused with it. The term electromotive force is an unfortunate one since it is not a force at all, but rather work or energy. The term *voltage* is a common, though "loose" expression, being used for potential difference, or E.M.F., or both.

The practical unit of potential difference or of E.M.F. is the *volt.* It is the electromotive force needed to drive a current of one ampere through a resistance of one ohm. Potential difference is measured by means of a voltmeter. The length of a properly designed spark gap may also be used, under suitable conditions, to measure large differences of potential.

Ohm's Law.—The current, voltage, and resistance in a simple circuit are definitely related. The formula expressing this relation is

[1] The process will be discussed in the consideration of the passage of radiation through matter.

known as Ohm's law, and states that the intensity of the electric current along a conductor equals the electromotive force divided by the resistance and may be expressed as

$$\text{amperes} = \frac{\text{volts}}{\text{ohms}} \text{ or } I = \frac{E}{R}$$

Accordingly, when any two of these factors are known, the third may immediately be determined.

Power.—Electrical power, like mechanical power, is the time rate of doing work; that is, the total work done, or energy used, divided by the time in which it is done. Since potential difference is of the nature of work per unit charge and current of electricity is the number of unit charges per second, it follows that the product of potential difference and current is work per second, or power. In the practical system of units, 1 unit of power, which is 1 ampere of current times 1 volt of electromotive force, is 1 *watt*. This may be expressed as

$$\text{watts} = \text{volts} \times \text{amperes}$$
$$\text{or}$$
$$W = E \times I$$

BIBLIOGRAPHY

ANDRADE, E. N. DA C.: The Structure of the Atom, London, G. Bell & Sons, 19 3.
CLARK, G. L.: Applied X-rays, 2d ed., New York, McGraw-Hill Book Company, 1932.
COMPTON, ARTHUR H., and ALLISON, SAMUEL K.: X-rays in Theory and Experiment, New York, D. Van Nostrand Company, 1935.
Handbook of Chemistry and Physics, 18th ed., Cleveland, Chemical Rubber Company, 1933.
HULL, GORDON F.: An Elementary Survey of Modern Physics, New York, The Macmillan Company, 1936.
MILLER, CARL W.: Introduction to Physical Science, New York, John Wiley & Sons, 1935.
RASETTI, FRANCO: Elements of Nuclear Physics, New York, Prentice-Hall, 1936.
ROBERTSON, J. K.: Radiology Physics, New York, D. Van Nostrand Company, 1941.
RUTHERFORD, ERNEST, CHADWICK, JAMES, and ELLIS, C. D.: Radiations From Radioactive Substances, New York, The Macmillan Company, 1930.
STARLING, S. G.: Electricity and Magnetism, 6th ed., New York, Longmans, Green & Co., 1937.
WEBSTER, D. L.: Roentgen Ray Physics, in Glasser, O., ed.: Science of Radiology, Springfield, Ill., Charles C Thomas, 1933.

CHAPTER IV.

FUNDAMENTAL ELECTRICAL CONSIDERATIONS IN RELATION TO *X*-RAY APPARATUS.*

THE nature of electricity has been discussed in Chapter III, and brief mention made of electric currents. *X*-ray equipment consists entirely of apparatus for controlling electric currents. A brief description of the various instruments and devices which are combined to make the complete modern *x*-ray apparatus will greatly facilitate an understanding of its operation.

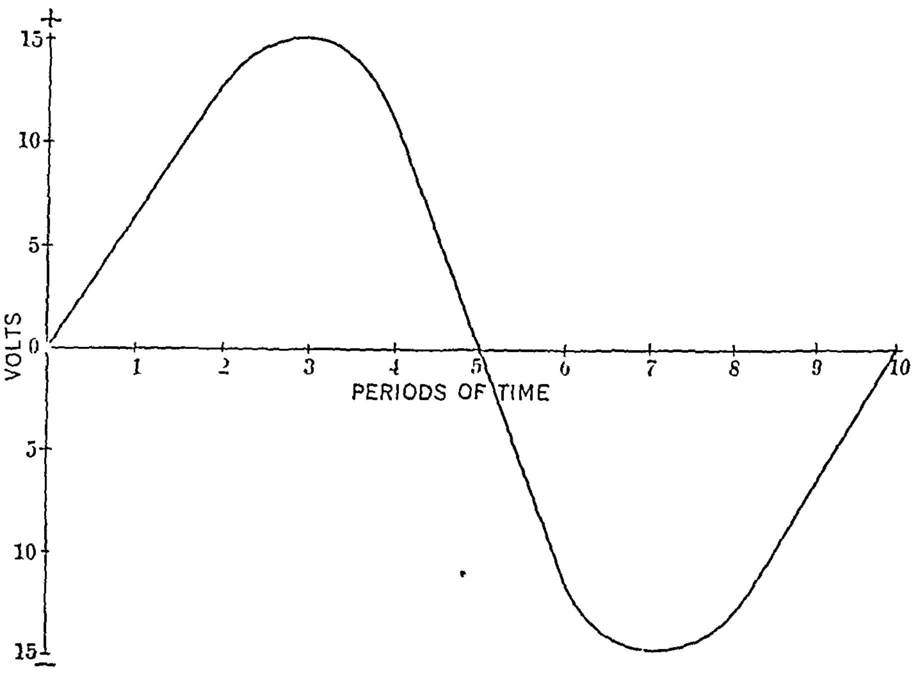


FIG 5.—Current-time curve of a simple alternating current circuit The diagram represents one cycle (0–10), or 2 alternations (0–5 and 5–10) in opposite directions

Electric Current; Direct Current; Alternating Current.—Electric current has been described as the passage of electricity along a conductor joining two other conductors which are at different potentials. If these *terminals* are maintained at the same different potentials, the flow of current will be continuous and uniform. When the current

* *In the last edition*, this chapter was revised by Edith H Quimby Some of the material added by Dr Quimby has been retained in this edition

flow is always in the same direction it is spoken of as *direct current* (D C) If, by any means, the two terminals are made to alternate in their charge so that at one time the flow is in one direction and at another in the other, the reversal being repeated at regular intervals we have *alternating current* (A C) Most generators in use at present supply A C The current, starting at zero at a given instant, rises to a maximum value falls to zero rises to a maximum of the opposite sign, and falls to zero again The complete alternation, from any one point to the corresponding point again, is called a *cycle* The usual alternating current has 60 cycles or 120 alternations per second Fig 5 shows the standard curve used to represent alternating current

Alternating current is supplied from the central power stations at fixed voltages according to the purpose for which it is to be used Most modern *x*-ray equipment is designed to operate on 220-volt, 60-cycle A C When only direct current is available, it is customary for the manufacturer to install a suitable rotary converter which changes the current from direct to alternating Obviously, before planning the installation of an *x* ray machine, one should investigate the source of power supply One should also make sure that the supply wires are heavy enough to furnish all the current that may be required

Condenser—The condenser is a device for temporarily storing electric energy Consider two conducting plates separated by an insulating layer such as mica One plate is connected to a source of potential and the other to ground If a negative charge is placed on the first plate it will repel electrons (negative charges) from the second plate These will pass to ground through the connecting wire, and leave an *induced* positive charge on the second plate The greater the charge on the first plate the greater the induced charge on the second These two charges of course, attract each other, if they become strong enough they may pierce the insulating layer If the two plates of a charged condenser be connected together by a wire the charges will neutralize each other in a bright thick *spark* If, however the plates are not short-circuited,' but the current is led away into an electric circuit containing other instruments it can be used to supplement current obtained in other ways

Electric and Magnetic Lines and Fields of Force—An electric charge is surrounded by a field of force which may be represented by lines of force going out from the charge in all directions Similarly a *magnet* is surrounded by a field of force the magnetic lines of force originating at the two poles An electric current consists of charges in motion in a conductor and such a conductor has been found to be surrounded by a *magnetic field* It appears that there are very close relations between electricity and magnetism and many electrical instruments depend on the interaction of the two

Electromagnet—A magnet has two poles called north and south As in electricity, like poles repel and unlike poles attract each other

There are two types of magnets, permanent and electromagnets. When a current is passed through a coil of wire, a magnetic field is set up. If a bar of soft iron is placed inside the coil, the magnetic field is increased. With D C. the magnet is steady; with A C. the position of the poles reverses just as often as the current alternates.

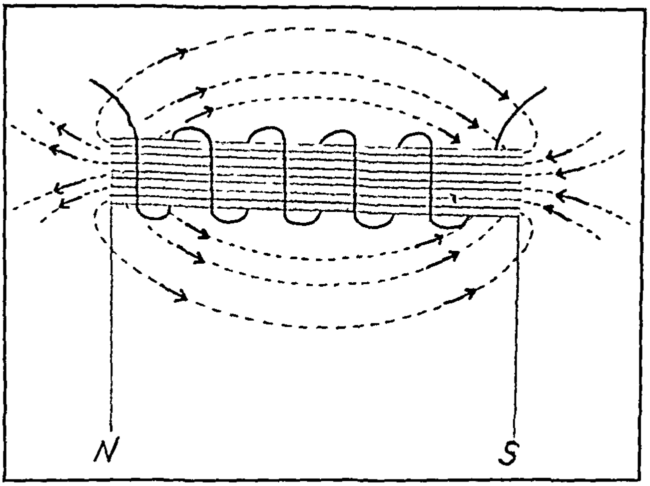


FIG 6 —Lines of force in an electromagnetic field The soft iron bar is magnetized by the passage of electricity through a coil of wire

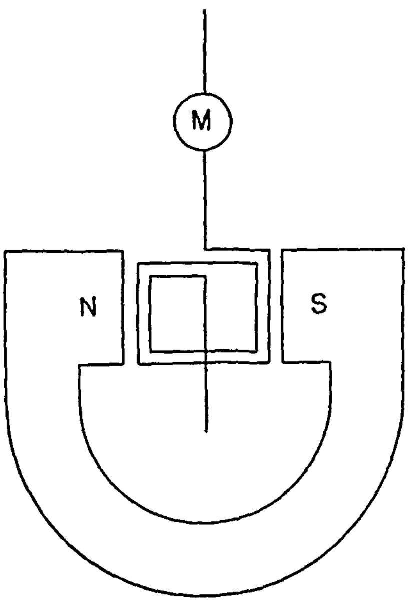


FIG 7 —Schematic drawing of galvanometer

Galvanometer —A light magnet suspended in a strong electric field or a light coil carrying current in a magnetic field, will move until it finds a stable position, where the field of the coil and that of the magnet just counteract each other. This property is made use of in various current and voltage measuring instruments A light coil

of wire is suspended between the poles of a permanent magnet as shown in Fig 7 If an electric current passes through this coil the interaction between its field and that of the magnet will cause it to turn on its fine suspension until it attains a position of equilibrium The greater the current the more the coil will turn A beam of light reflected from a small mirror mounted on the suspension, back to a scale, forms a weightless pointer to indicate the angle of turn In a sturdier type of instrument the coil may actually carry a pointer which moves over a scale

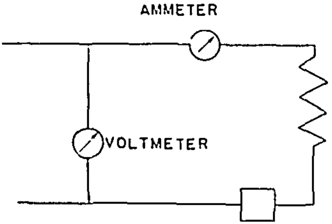


FIG 8 —Diagram showing methods of connecting ammeters and voltmeters in electric circuits

Ammeter, Voltmeter Galvanometers are classified in two types according to whether they have very low or very high resistance When the resistance is very low the instrument may be put anywhere in a circuit and its reading will be proportional to the current which passes through it An instrument of this type is called an *ammeter* (for very small currents a milliammeter or microammeter) Its scale is calibrated to read directly in amperes If the galvanometer has very high resistance it permits the passage of only a small current Such an instrument is connected between two points in the circuit which have an alternative connection of lower resistance through which most of the current will pass With a definite resistance the small current which does pass through the galvanometer is proportional to the potential difference between its terminals Such an instrument can be calibrated to read directly in terms of the potential difference in volts and is called a *voltmeter* An ammeter is connected directly into the circuit whose current is to be measured A voltmeter is connected as a subsidiary circuit or *shunt* between two points in the circuit whose potential difference is to be determined (Fig 8)

Electromagnetic Induction —When a wire is moved in a magnetic field, a current is set up or *induced* in the wire The strength of this current depends on the number of lines of force passed through, or *cut*, by the wire per second Thus it might move more slowly through

a strong field or more rapidly through a weak one and produce the same result As the wire moves in one direction across the lines, the current flow is in one direction, when the motion of the wire is reversed, the direction of the current is also reversed. Current is produced in the same way if the wire remains stationary and the magnet moves This phenomenon is called *electromagnetic induction.*

It is not even necessary to have an actual magnet It was stated above that a magnetic field surrounds a coil carrying a current. As a matter of fact, the coil itself acts as a magnet. If the current flowing in it is D.C., the coil (called a *solenoid*) exhibits definite north and south poles If A C is used, the poles also alternate Another coil moved across the lines of force of the first one has a current induced in it.

It is not even necessary to have either coil move, it is only essential that the lines of force move relative to the wire When there is no current in a coil, it has no field of force. The instant the current starts, lines of force emerge from it in all directions. They therefore move relative to any other coil which happens to be in the neighborhood, and induce in it an instantaneous current. This ceases to flow as soon as the current in the first coil has reached a steady state, for there is then no relative motion of lines of force and wires When the current in the first coil stops and the field collapses, there is another momentary current in the second, in the opposite direction to that which resulted from the building up of the field If D.C. is started and stopped often in the first coil, an A C. is set up in the second.

THE HIGH VOLTAGE SUPPLY.

Induction Coil.—An induction coil is an apparatus for generating an induced current in the manner just described It consists of two coils of wire, the *primary,* in which the original current is started and stopped, and the *secondary,* in which the induced current is developed. In general, the primary consists of a relatively small number of turns of heavy wire, wound on an iron core, as shown in Fig 9 The secondary consists of many turns of much finer wire, wound outside the primary, every turn, of course, being insulated from all the others. The voltage generated in the secondary bears approximately the same relation to that in the primary as the number of turns in the two coils Therefore, an induction coil can be used to obtain high voltage when a low voltage supply is available While the voltages in the two coils are directly in the ratio of the numbers of turns, the ratio of the currents is the inverse of this Thus, the product of the current and voltage in the primary is equal to the product of the current and voltage in the secondary The energy (watts) supplied to the primary is the same as that which comes out of the secondary There is no power loss The coils are usually wound over a metal core to concentrate the field and make the efficiency of transfer as great as possible.

Since current is generated in the secondary only when it is started or stopped in the primary, some means is necessary for starting and stopping or *interrupting* the primary current regularly and frequently

Interrupters —Many schemes have been developed for this purpose The one shown in Fig 9 is the simplest The *hammer* is constructed of soft iron mounted on a spring When no current is flowing in the primary, the rest position of the hammer is such that the two points are in contact When current starts to flow in the primary, the iron core becomes magnetized and attracts the hammer, thus separating the points This interrupts the current in the primary the magnet ceases to function, the hammer returns to its rest position and the cycle is repeated Thus, the hammer vibrates back and forth, and with every *interruption of the primary current, the secondary current* is generated

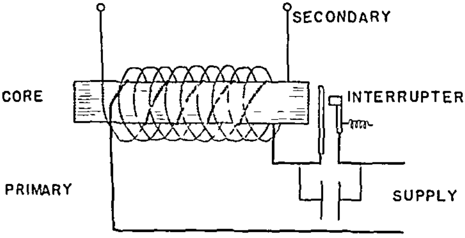


Fig 9 —Schematic drawing of induction coil and interrupter

The condenser is not an essential part of the circuit, but is a valuable adjunct Since the magnitude of the induced current depends on the rate at which the lines of force are cut it is evident that the faster the field is developed or collapses the greater will be the induced current The collapse, occurring at the *break* of the circuit, is always faster and hence the secondary current produced thereby is greater than that at the *make* of the current This latter is called the *inverse current* since it flows in the opposite direction to the first (and more important) If unidirectional current is desired, an effort is made to suppress the inverse This can be partially done by building up the field very slowly in contrast to its rapid collapse The condenser is used for this purpose Connected in the primary circuit, it receives and restores the first rush of current at make, allowing the field to build up slowly At break it discharges suddenly, with consequent sudden demagnetization of the core and collapse of the field

There are various other types of interrupters more practical for heavy duty than the hammer break Since, however, induction coils are

seldom used at the present time, there is no need of going into details with respect to them.

Transformer.—The induction coil is used with direct current, which must be interrupted However, today most power is supplied in the form of alternating current If the primary of an induction coil were activated by alternating current, its magnetic field would vary automatically in strength and direction with the periodic changes in the current. As a result of these changes, alternating current would also be induced in the secondary. A transformer is a particular type of induction coil. Instead of an intense, abrupt flow of secondary current at break, and a smaller inverse one at make, with a perceptible interval of no current, as is the case with the induction coil, the current in the secondary of the transformer is smoothly alternating, following the same general form as in the primary. As in the induction coil, the

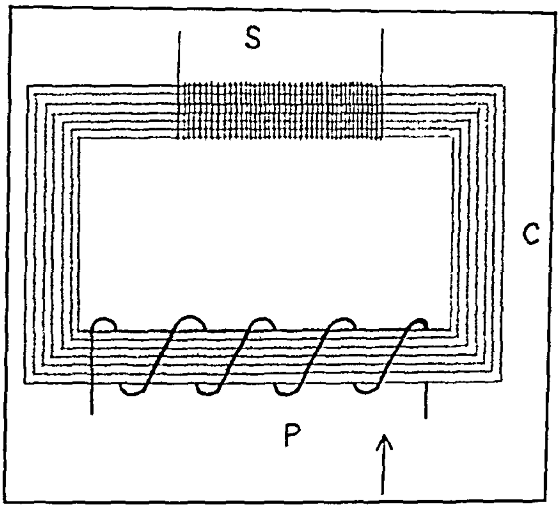


FIG 10 —Closed core step-up transformer *C*, Core made up of laminated soft iron bars, *P*, primary coil, *S*, secondary coil

coils of the transformer are usually wound about a metal core In general, the cores of induction coils are straight (open magnetic circuit) On the other hand, the cores of transformers are usually rectangular or toroidal in shape (closed magnetic circuit), the primary being wound on one side of the core and the secondary on the other side. The primary and secondary voltage and current ratios bear the same relation to the numbers of turns as in the induction coil If the number of turns in the secondary is greater than that in the primary, the secondary voltage will be greater than the primary, and the transformer is of the *step-up* variety. If the secondary has fewer coils than the primary, the secondary voltage is less than the primary and the transformer is of the *step-down* type. Since the main power supply is usually at 110 or 220 volts, and both higher and lower voltages are necessary in different parts of the *x*-ray circuit, both types of trans-

former are used Step-up (high voltage) transformers are employed to energize *x*-ray tubes and step-down (low voltage) transformers are used to energize the filaments of *x* ray and valve tubes

DEVICES USED FOR CURRENT CONTROL.

Autotransformer—In any coil carrying an alternating current, the magnetic field produced by any turn of the coil is cut by all the other turns, so that a current is induced in them Induction of current in a coil by cutting its own lines of force is called *self induction*, as opposed to induction in a secondary coil which is known as *mutual induction* Self induced current in a coil always has its electromotive force in the

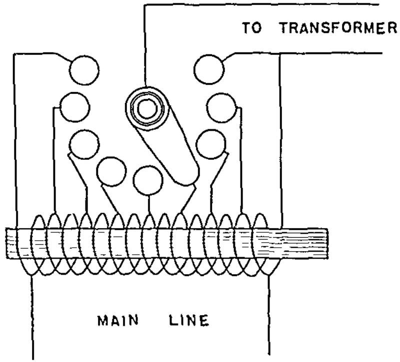


FIG 11 —Schematic drawing of autotransformer control

direction opposite to that of the primary current, that is, the self-induced current opposes the primary current, and therefore reduces it The resistance of an inductive circuit to the passage of an alternating current is called the *impedance* Such a coil, with a means of changing the number of turns included in the circuit can be used to control the primary current, for the more turns are used, the greater is the self-induction and hence the greater the opposition to the primary current Such an instrument is called an *autotransformer* it is diagrammed in Fig 11, as used to control the current in the primary circuit of the *x*-ray transformer With the lever on the last button current coming from the main line must flow through the whole coil before it gets to the transformer, and the self-induction effectively reduces it to a small

amount As the current is to be increased, successive buttons cut out more and more of the autotransformer coil.

Rheostat.—Another important instrument of control in the primary circuit is the *rheostat*, or *resistance*. It consists simply of a series of coils of wire which oppose the passage of the electric current and dissipate part of its energy in the form of heat. A schematic representation of a rheostat is given in Fig. 12. With the lever arm on the last button, the current must pass through all the coils. For a given current, this causes a very high voltage drop across the rheostat, since volts = amperes × ohms. This means that very little of the primary voltage is left to go on to the transformer. As successive resistance coils are cut out, more voltage is left to reach the transformer

Autotransformer and Resistance Control.—Each of these instruments fills a definite function, and the combination of the two has been found more satisfactory than either alone. For a given change in current, the

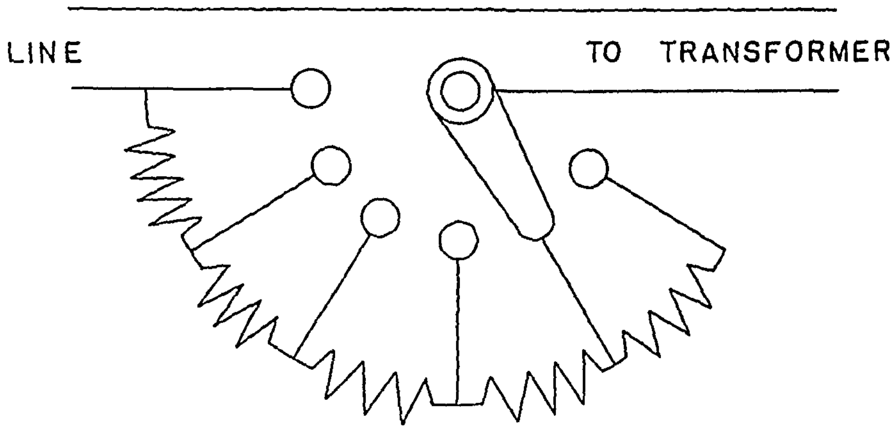


FIG 12 —Schematic drawing of rheostat control

voltage varies less with autotransformer than with resistance control For the original warming up of the tube, it is desirable to approach the high voltage gradually, hence the resistance control is used. Once the desired voltage is reached, it is desirable to have as little variation as possible with change of tube current. If the entire control is by rheostat, every change in tube current is accompanied by a corresponding change in voltage For instance, if the milliamperes are increased, the voltage will drop. This is because the energy consumed in the rheostat (amperes × ohms) increases, leaving less to go on to the transformer Accordingly, in order to get back to the original voltage, it is necessary to cut out more of the rheostat. Some variation occurs even with autotransformer control, but it is less Both instruments are ordinarily used It is customary to determine the desirable position for the autotransformer for a given kilovoltage and milliamperage, and to set this before starting the x-ray apparatus. Control is then maintained by means of the rheostat

Fuses — As long as no accident occurs an x ray circuit once established should operate steadily But as a result internally of breakage or short circuit, or externally, of surges on the power line, a current much too large may be momentarily supplied to the primary of the transformer In order to prevent this from doing damage, *fuses* are inserted in the circuit A fuse is simply a strip of metal which melts when a certain amount of electricity traverses it thus opening the circuit Fuses are carefully rated for different amperages They should be used for a rating somewhat higher than the maximum load to be carried by the circuit, but not too much higher *A fuse should never be replaced by a permanent connection* If a fuse blows out repeatedly it means that there is something definitely wrong in the apparatus

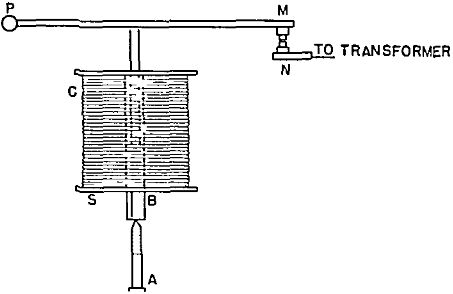


FIG 13 —Schematic drawing of circuit breaker

Circuit Breaker —More rapid and more certain action than that of fuses is desired in x ray circuits and for this purpose a *circuit breaker* is used This is simply a coil carrying a current (a solenoid), with a movable soft iron plunger arranged as shown in Fig 13 Through coil C wound on a spool S passes a current which is proportional to the full transformer current This solenoid acts as a magnet and draws up into itself the soft bar of iron B to a definite position If the current in C is increased somewhat, the magnet of the solenoid becomes stronger and the plunger is drawn farther up If enough current passes through C B will be drawn up so far that it pushes up the bar P, opening the contact at MN which is in the main line to the transformer primary Thus when a sudden surge traverses the supply line, the circuit breaker is activated and interrupts the flow instantly Some breakers are so constructed that when the danger is over they return to the original position and the circuit is again closed In others,

it is necessary to close the breaker by hand before the machine can be started again. By means of the adjustable screw, *A*, the position of the plunger can be regulated so that the circuit will be broken for any specified current.

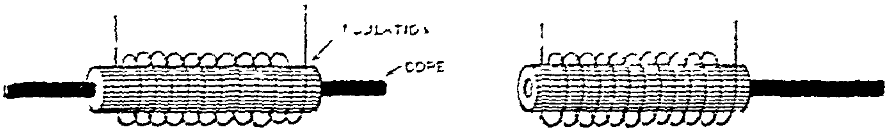


FIG. 14.—Choke coil for regulating current for Coolidge filament.

Choke Coil.—A type of autotransformer often used for controlling small currents is the *choke coil.* It is shown in Fig. 14, and consists merely in a coil-carrying current, wound over a movable iron core. The position of the core influences the amount of self-inductance in the coil. As has been stated, self-induced currents have an E.M.F. tending to oppose the passage of the primary current. Therefore, by moving the metal core in or out of the coil, the primary current may be regulated.

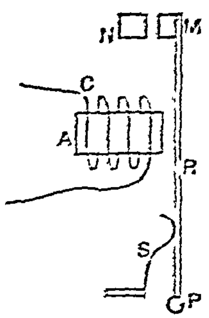


FIG. 15.—Contactor.

Contactor.—It is generally not desirable to have ordinary switches carry the whole current for the transformer primary. Accordingly, a *contactor* is used which may be activated by a small part of the current. It is shown in Fig. 15. The coil *C*, wound on the soft iron core *A*, carries a small part of the main current. *R* is a strip of iron pivoted at *P*. When the switch at the contactor is closed, and current passes in *C*, *A* becomes magnetized and attracts *R*, which swings toward it, bringing *M* and *N* into contact. These points are in the main circuit, through which current can then pass.

THE HIGH VOLTAGE CIRCUIT.

Rectification.—The secondary of a transformer delivers alternating current. If this were conducted to the terminals of the *x*-ray tube, each one would be charged alternately positively and negatively 60 times a second. In order for electrons to be repelled from the filament

and attracted to the target as is essential for *x*-ray production, the former must be negative and the latter positive. Therefore it is necessary to have some means of either suppressing that part of the current which has the wrong sign or of directing its course so that it always gets the *appropriate terminal of the x-ray tube*. In practice both of these courses are adopted. The so-called *mechanical rectifiers* direct the course of the current into the proper channel, the electrical or *thermionic*, scheme may do either, depending on the system used.

Self Rectification.—Self rectification occurs when the high voltage terminals are connected directly to the terminals of the *x*-ray tube. As long as the target is cold the negative phase of the alternating current is suppressed by the *x*-ray tube. The heated filament supplies electrons and these are attracted to the target when the filament is negative and the target positive. During the reverse half cycle of the alternating current, no current flows from the filament to the target. When the target is hot, electrons are emitted from both filament and target and the system breaks down.

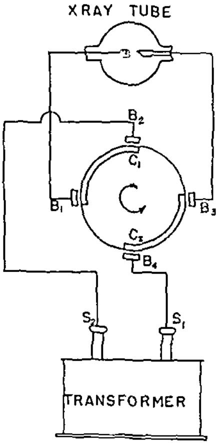


FIG. 16.—Schematic representation of transformer mechanical rectifier (disc type) and *x*-ray tube.

Mechanical Rectifiers.—The mechanical rectifier is simply a rotating switch, mounted on an axis turned by a *synchronous motor*, so that it rotates exactly as often as the circuit alternates, and is always at the same position at the same phase of the secondary current. A schematic representation of one type of mechanical rectifier is given in Fig. 16. *C1* and *C2* are metal conductors slightly longer than one-fourth the circumference of the disc which carries them. This is mounted on an axis turned by a synchronous motor 30 times a second (for 60 cycle current). *B-1-2-3-4* are stationary metal brushes which just fail to touch the disc as it rotates. In the position illustrated, one end of the transformer secondary *S1* is connected through *B4* to *C2-B3* and the right-hand end of the *x*-ray tube. One half cycle later, when *S1* and *S2* are reversed in polarity the disc has made a one quarter turn so that *C1* extends from *B4* to *B1* and *C2* from *B2* to *B3*. Thus, current from *S1* goes now *via B4-C1-B1* to the left hand of the tube. The current *from S2* may be similarly traced. In this manner, as the polarity of the

in the transformer, *S2* and *X* become negative, and electrons are repelled from *Y*. Similarly, they are attracted to *A*. They cannot pass through the valve tube in this direction, and must pass through the *x*-ray tube Each condenser develops a potential almost equivalent to the maximum of the transformer, and the potential difference across the tube is equal to the sum of these, or almost twice the transformer voltage.

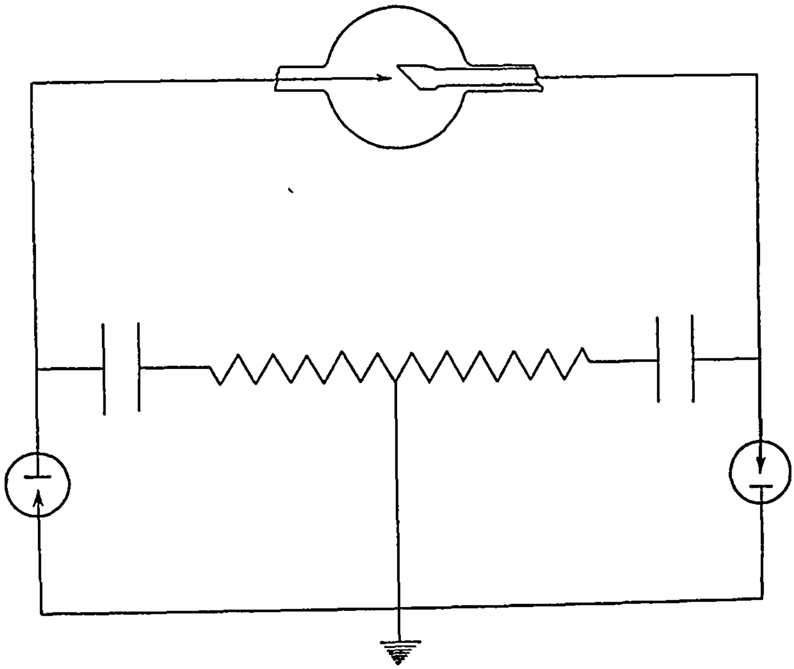
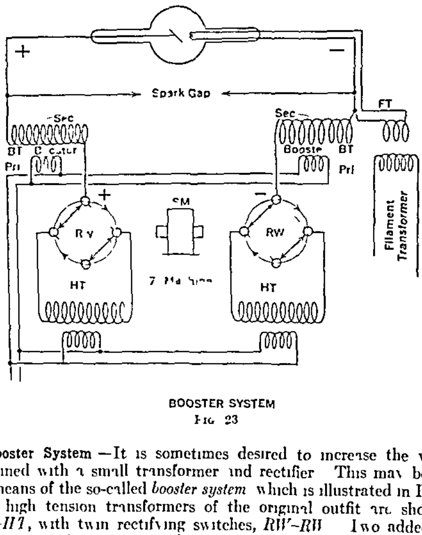


Fig 22 —Voltage doubling valve tube circuit, Garretson circuit

Various modifications of the circuits with and without condensers are used In some, the mid-point of the transformer is grounded, or two transformers are used, each with one terminal grounded, and the kenetrons also grounded at one terminal. Such a circuit is the Garretson, shown in Fig 22 This modification permits the introduction of the milliammeters at ground potential, which advantage is discussed in connection with twin type transformers It also makes it possible to combine each valve tube and condenser pair into a unit which may be immersed in oil, simplifying insulation problems.

Twin Type Transformer.—Instead of a single transformer and rectifying switch, two are frequently used, each of one-half the capacity necessary in a single one, thus permitting smaller and more compact installations In this case one terminal of each transformer is grounded, and the rectifier has merely to care for the current from the active terminal as it alternates It may be mentioned that in such an installation the milliammeters can be put in the grounded side of the circuit, thus making it possible to mount them on the control board in a favorable position for close observation.

Polarity Indicator.—It is not sufficient to insure unidirectional current through the x-ray tube, it must pass in the *correct direction*. That is, the negative terminal of the secondary must always be connected to the filament in order that the electrons may be repelled from it and attracted to the target. Since at the instant of starting the machine either terminal may be positive, a *polarity indicator* is mounted on the control panel to show which way the current starts. This is ordinarily a simple D.C. voltmeter in connection with a commutator to rectify a small current tapped off the A.C. supply.



BOOSTER SYSTEM
FIG. 23

Booster System.—It is sometimes desired to increase the voltage obtained with a small transformer and rectifier. This may be done by means of the so-called *booster system*, which is illustrated in Fig. 23. The high tension transformers of the original outfit are shown at *HT–HT*, with twin rectifying switches, *RW–RW*. Two added *high tension transformers* are *indicated* at *BT–BT*, which are used for doubling the voltage of the original pair. The primaries of the two pairs of transformers are connected in parallel. One terminal of each of the *BT* transformers is connected to one terminal of the rectifier, the other leads to the x-ray tube.

The rectifying switches are so set that the current from the right hand *one* is *always negative* and *from the other always positive*. Hence they deliver from the secondaries of the first (*HT*) transformers,

to the secondaries of the *BT* transformers a unidirectional current which pulsates between zero and the maximum for the *HT* transformer In these same secondaries the *BT* transformers themselves produce an alternating current at the same potential as the *HT* transformer At a given instant, the polarity of the current due to the *BT* transformer itself, and that delivered by the rectifier from the *HT* transformer, will be opposite, the two currents counteract each other, and no current passes to the *x*-ray tube On the next half cycle, the polarity of the two is the same, the voltages are additive, and the potential difference across the tube is twice that which it would have been with the original transformer

Only alternate half waves are utilized in this system, the other half being suppressed. However, the output is effectively the same as if both halves were used when the milliammeter reading is the same. This may be explained when it is realized that the current is really pulsating, fluctuating between zero and a maximum. These fluctuations are too rapid for the milliammeter to follow, and it registers an average Evidently this average will depend on the number of fluctuations per second, and the size of each, the same result can be obtained by fewer larger ones or more smaller ones. When one-half the waves are suppressed, twice as much current must be drawn from the other half.

THE COMPLETE X-RAY APPARATUS.

Having discussed the component parts of the *x*-ray apparatus, we may now combine them into a typical circuit, such as is given in diagram in Fig 24. This shows a valve tube rectifier outfit with two transformers and two rectifying tubes

Ordinary *x*-ray equipment used for therapy may be divided into 4 partly separate circuits

1. Circuit for the high tension transformer
2. Circuit for the *x*-ray tube filament
3. Circuit for the valve tube filament or the mechanical rectifier circuit if the equipment is of the old type
4. Connections to switches, meters and other accessories

The usual source of current is 220 volts A C It is fed to a main switch, and from there it is diverted into 3 separate channels. They are (1) autotransformer and resistance control, (2) valve tube filament transformer, and (3) *x*-ray tube filament transformer The autotransformer and the rheostat are connected to the primary of the high tension transformer There is a voltmeter across the primary of the high tension transformer and a milliampere meter in the high tension circuit The voltmeter measures the E M F. in the primary of the high tension transformer and the milliampere meter measures the milliamperes passing through the *x*-ray tube after leaving the secondary of the high tension transformer The high voltage alternating current has to be rectified to high voltage pulsating direct

current. This is done either by valve tubes or by mechanical rectifiers. Modern equipment has valve tube rectification. There are 2 separate circuits entering a valve tube. One circuit is from a step-down transformer for the purpose of heating filament and the other circuit is from the high tension transformer. The high tension current now passes from the valve tube to the *x*-ray tube. Like the valve tube there are 2 circuits passing to the *x*-ray tube. One circuit is a low voltage from a step-down transformer for the purpose of heating the filament, and the other is the high voltage circuit from the valve tube.

Filament regulators, circuit breakers, current stabilizers, double milliampere meters, and other refinements are found in good equipment. Details of different types of apparatus will not be discussed. It is the purpose of the section simply to enumerate the essential component parts of an *x*-ray apparatus. The diagram in Fig. 24 should help the reader to visualize better the relationship of these parts.

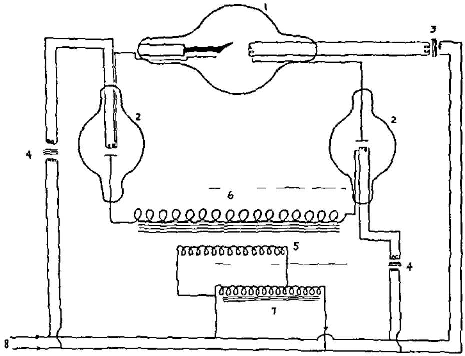


Fig. 24.—Main circuit of a two valve tube *x*-ray equipment. *1*, X-ray tube; *2*, two valve tube; *3*, low tension transformer for the *x*-ray tube; *4*, low tension transformers for the two valve tubes; *5*, primary coil for the high tension transformer; *6*, the secondary coil for the high tension transformer; *7*, autotransformer; *8*, lead from the 220 volt alternating current source. The black lines carry the supply current, the red line carries the high tension current, and the blue line carries the low tension current.

THE MEASUREMENT OF HIGH VOLTAGE

Spark Gap.—Until recently the only means of measuring high voltage outside well equipped physical laboratories was the spark gap and even at present it is more widely used than any other method

The spark gap measures the *peak* voltage. Since the wave form from different types of generators may vary greatly, even when the same peak voltage is delivered (Fig. 25), it is evident that the spark gap will not give complete information regarding the quality of the radiation. It will permit the determination of the *minimum wave length*, but tells nothing about how much of the radiation is of this wave length, or what is the distribution of the remainder. (See discussion of Quality Determination, Chapters IX and X.)

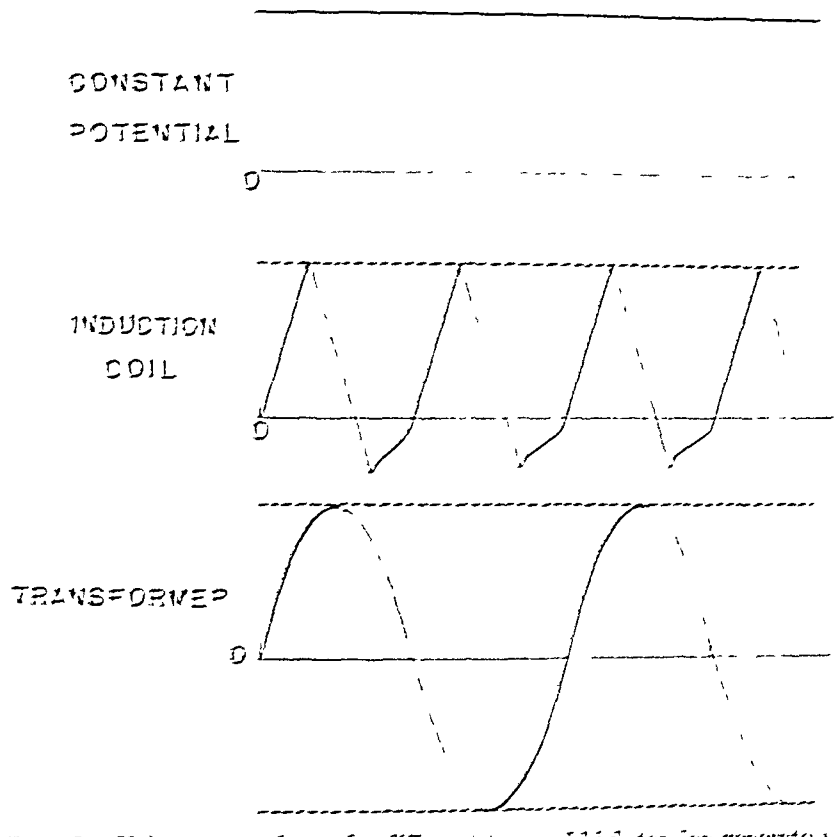


FIG. 25.—Voltage wave forms for different types of high-tension generators.

The design of the spark gap is of great importance. Less potential difference is necessary to cause a spark to cross a given distance between sharp points than between blunt ones. As the blunt ends are enlarged into balls, still more potential difference is needed, and this increases as the size of the sphere increases. Table 1, taken from the *Handbook of Physics and Chemistry*, 19th ed., 1935, Chemical Rubber Company, Cleveland, Ohio, gives the spacing for specified peak voltages for different types of gap.

The so-called *effective voltage* for alternating current is about 70 per cent of the peak voltage. This term was formerly commonly used in specifying x-ray voltages, but has now been largely abandoned in favor of peak voltage.

Spark-gap measurements are subject to many errors. In the first place, the personal equation is large. The rate of speed at which different observers close the gap, the method of holding it in position and of reading it are important. Spark-gap measurements should never be made by setting the gap at a fixed position and increasing the voltage through the apparatus until the spark passes. The presence of even small surges on the line makes accurate measurements by this method impossible. The gap should be set much wider than necessary, the apparatus brought to a steady running condition, and the gap closed slowly. Care must be taken not to close the gap farther after the spark has passed. Several readings must always be made and the average taken to obtain the value to be used. The sparking points or surfaces should always be clean and free from rust or moisture.

TABLE 1.—SPARK-GAP VOLTAGES (25° C, 760 MM PRESSURE)

Peak voltage, kv	Length of spark gap, cm: Sharp point	Spherical electrodes: 2.5-cm spheres	5-cm spheres	10-cm spheres
40	3.81	1.41	1.30	1.29
60	6.81	2.8[illegible]	2.17	2.0[illegible]
80	11.10		3.26	2.84
100	15.50		4.77	3.75
120	19.80		7.07	4.78
140	24.10			5.97
160	28.10			7.37
180	32.00			9.03
200	35.70			11.10

Spark-gap measurements should never be made in such a way as to throw a large current across the valve tubes. They are adjusted to carry any current tolerated by the x-ray tube, but not the much larger one passed by the gap at spark-over. The gap is introduced into the circuit in such a way as to short circuit the x-ray tube so that it is protected. Methods of determining voltage in valve tube installations are discussed below.

TABLE 2.—CORRECTION FOR SPHERE-GAP VOLTAGE READING WITH TEMPERATURE AND PRESSURE (Handbook of Physics and Chemistry, 193[illegible], courtesy of Chemical Rubber Company, Cleveland, Ohio.)

Temp., C	Pressure, mm: 720	740	760	780
0	1.04	1.06	1.09	1.12
10	1.00	1.0[illegible]	1.05	1.08
20	0.96	0.99	1.02	1.04
30	0.93	0.96	0.98	1.01

Variations in temperature, pressure and humidity cause variations in the spark-gap readings. Table 2 gives correction factors for temperature and pressure within certain limits. If the temperature is lower than the 25° C. of the standard table, more potential difference

will be required to make the spark jump a given gap, or a given space will indicate a higher voltage than the correct one by the amount in the table. Similarly, if the pressure is lower than the standard 760 mm., less voltage is necessary to force a spark to jump a given gap. Therefore, the correct reading will be lower than the apparent one, by the factor indicated. For the greater variations in pressure due to changes in altitude rather than to local barometric conditions, the correction factors given in Table 3 may be used.

TABLE 3.—CORRECTION FOR SPHERE-GAP VOLTAGE READING WITH ALTITUDE (Handbook of Physics and Chemistry, 1935, courtesy of Chemical Rubber Company, Cleveland, Ohio)

Altitude, ft	Normal pressure, mm	Correction, percentage of sea level value
0	760	100
1000	730	96
2000	705	93
3000	680	89
4000	655	86
5000	630	83
6000	605	80
7000	580	77
8000	555	74

For altitudes such that normal barometric readings do not come within the range of Table 31, temperature corrections may be obtained from Table 4.

TABLE 4.—CORRECTION FOR SPHERE-GAP READING WITH TEMPERATURE (Handbook of Physics and Chemistry, 1935, courtesy of Chemical Rubber Company, Cleveland, Ohio)

Temp., °C.	Correction, percentage of value at 25° C
0	109
5	107
10	105
15	103
20	102
25	100
30	98

The effect of humidity varies with the size of the sparking terminals, being more marked for points than for spheres Rather than attempt to correct for humidity, it is wise not to make spark-gap measurements on a very damp day.

With reasonable precautions, spark-gap measurements are quite reliable. However, at present they need be used only for an occasional check. The modern x-ray equipment is always provided with a voltmeter in the primary circuit, which may be calibrated to give the secondary voltage. This calibration is done by means of the spark gap, and must be made with the voltmeter on the apparatus with which it is to be used. It will not apply even to another apparatus of the same type, because of possible slight differences in transformation and

rectification Calibration must be made for every combination of kilovolts and milliamperes which may be used, since with different currents the same primary voltage will give different secondary voltages (See section on Autotransformer and Rheostat Control) For instance, the first determination might be to find the voltmeter setting which, with 2 milliamperes caused the gap to break when the voltage was 100 kilovolts, as determined from a table for the proper type of terminal Suppose this reading was 90 Then, as long as no breakdown occurred in the apparatus, whenever the primary voltmeter registered 90, with a current of 2 milliamperes, the secondary voltage would be 100 If, however, the current is increased to 4 milliamperes, the reading on the voltmeter when the spark gap indicates 100 kilovolts will be more than 90, possibly 102 That is, with increased current, greater primary voltage is necessary to obtain a given secondary voltage It is evident, therefore, that separate calibrations must be made for every combination of kilovolts and milliamperes which may be used These calibrations will remain constant as long as no change occurs in the apparatus or the tube It is advisable to check this from time to time with a spark gap, but routinely, reliance may be placed on the primary voltmeter

It is evident from the above that the primary voltmeter scale should not be made to read directly in kilovolts, since the same reading indicates different kilovoltages depending on the tube current At present this explanation is of limited value because modern shockproof x ray apparatus is so designed that the operator cannot measure high voltage with gaps The measurements and calibrations of the voltmeters are made and guaranteed by the manufacturers Spark-gap measurements, even though inaccurate, were valuable with old type equipment, especially with all the variables common to such x-ray machines The introduction of more accurate methods of measuring quality and quantity of x ray beams by ionization has made gap measurements obsolete Besides, some shockproof therapy equipment have meters on the control panel which show kilovolt readings

Direct Measurement of High Voltage —The well-known relation between voltage, current, and resistance, known as Ohm's law, is utilized for the direct measurement of high voltage Resistors of known measurements are used the milliamperes are simply determined and, by utilizing the formula

$$\text{volts} = \text{amperes} \times \text{ohms}$$

the voltage is quickly determined The resistors are large and this work can be done only by physicists with specially equipped physical laboratories This is not a procedure which can be carried out by any dermatologist or roentgenologist

Indirect Voltage Determination by Means of Standard Absorption Curves —For x-ray apparatus giving constant potential, a very satisfactory method of voltage determination is by the comparison of

absorption curves[1] of the x-rays generated with standard curves. With constant potential, the quality of the rays is determined by the voltage, since it is practically all of the peak value, and no wave form need be considered The Bureau of Standards has published sets of absorption curves in aluminum and in copper for thin and thick glass x-ray tubes, for a wide range of voltage.[2] Tables 5 and 6 give the data for a thin glass tube with aluminum and with copper.

TABLE 5 —ABSORPTION OF GENERAL X-RADIATION IN ALUMINUM, DIFFERENT CONSTANT POTENTIALS TUBE WALL, 1 29 MM CERIUM GLASS

Al filter, mm	60 Kv	70 Kv	80 Kv.	90 Kv	100 Kv	110 Kv.
	Per Cent Radiation Transmitted					
0	100	100	100	100	100	100
1	32 10	33 80	36 00	38 90	40 30	42 40
2	19 00	20 80	22 90	25 20	27 20	29 40
3	12 80	14 40	16 50	18 40	20 30	22 30
4	9 34	10 70	12 60	14 40	16 20	18 00
5	7 00	8 44	10 10	11 60	13 40	15 00
6	5 41	6 79	8 25	9 69	11 30	12 80
7	4 35	5 53	6 88	8 33	9 80	11 20
8	3 55	4 61	5 84	7 21	8 58	9 92
10	2 44	3 42	4 38	5 44	6 63	7 85
15	1 16	1 79	2 40	3 17	4 06	4 80
20		1 00	1 40	2 01	2 60	3 17

TABLE 6 —ABSORPTION OF GENERAL X-RADIATION IN COPPER, DIFFERENT CONSTANT POTENTIALS TUBE WALL, 1 29 MM CERIUM GLASS

Cu filter, mm	100 Kv	110 Kv	120 Kv	130 Kv.	140 Kv	150 Kv
	Per Cent Radiation Transmitted					
0	100	100	100	100	100	100
0 14	20 40	22 00	23 80	25 80	27 60	30 30
0 20	15 30	17 80	19 90	21 80	23 40	25 60
0 25	12 90	15 10	17 40	19 20	20 80	22 80
0 30	11 10	13 20	15 20	17 00	18 70	20 50
0 40	8 78	10 30	12 10	13 80	15 40	17 00
0 50	7 15	8 50	10 00	11 60	13 00	14 40
0 75	4 53	5 77	7 04	8 32	9 55	10 70
1 00	3 08	4 13	5 18	6 35	7 41	8 43
1 50	1 77	2 42	3 13	4 00	4 86	5 75
2 00	1 03	1 60	2 06	2 73	3 38	4 13
2 50		1 02	1 46	2 00	2 50	3 12
3 00			1 09	1 48	1 93	2 49

For any setting of a therapy machine, an absorption curve may be taken with a simple ionization instrument By comparing the points of this curve with those of Tables 5 and 6, the voltage which produces radiation corresponding to this absorption curve can be found.

[1] For a discussion of absorption curves, see Chapter IX

[2] Bureau of Standards Research, Paper No R P 666, for sale by the Superintendent of Documents, Washington, D C, for five cents

This question of determining high voltages boils down to the use of sphere gaps for non-shockproof apparatus, and, for modern shockproof equipment, the meters mounted on the panel board read kilovolts in relation to certain milliamperes This is sufficient for practical purposes in dermatologic x-ray therapy For experimental purposes the aid of a physicist is required to make accurate absorption curves, and the voltages are then determined by comparison with standard absorption curves

BIBLIOGRAPHY

CLARK G L Applied X rays 2d ed New York McGraw Hill Company 1932

DUFF A WILMER and others A Text Book of Physics Philadelphia P Blakiston s Son Co Various editions

GILBERT N E Electricity and Magnetism Rev ed New York The Macmillan Co 1941

GLASSER O ed Medical Physics Chicago Year Book Publishers 1944

GLASSER O QUIMBY E TAYLOR L and WEATHERWAX J Physical Foundations of Radiology New York Paul B Hoeber Inc 1944

Handbook of Chemistry and Physics 19th ed Cleveland Chemical Rubber Company 1935

MILLER CARL W Introduction to Physical Science 2d ed New York John Wiley & Sons 1935

SIEGBAHN MANNE Spektroscopie der Rontgenstrahlen 2d ed Berlin Julius Springer 1931

STARLING S C Electricity and Magnetism 6th ed New York Longmans Green & Co 1937

TAYLOR LAURISTON S Apparatus for the Measurement of High Constant or Rippled Voltages Radiology 16 893 1931

TAYLOR LAURISTON S and SINGER GEORGE Standard Absorption Curves for Specifying the Quality of X Radiation Bureau of Standards Research Paper No R P 666 1934

TERRILL H M and ULREY C T X ray Technology New York D Van Nostrand Company 1930

United States Army X ray Manual 2d ed New York Paul B Hoeber Inc 1932

CHAPTER V.

RADIATIONS IN A DISCHARGE TUBE.*

MODERN *x*-ray tubes take many forms, depending on the purpose for which they are designed. All tubes will not be described, nor is it necessary to describe the evolution of *x*-ray tubes. In a practical book of this type we shall limit the discussion to: (1) Coolidge *x*-ray tube; (2) a typical shockproof tube; (3) Grenz ray tube; (4) tube used for contact therapy. The principles of operation of all *x*-ray tubes are the same and all come under the heading of *hot cathode tubes.*

Coolidge Tube.—The tube consists of a glass envelope with 2 long side arms. The glass is usually pyrex and resists heat, jarring, and pressure quite adequately. The vacuum is as perfect as is possible to obtain. It is about 1 billionth of an atmosphere of pressure. The electrons are emitted from a tungsten filament heated to incandescence by means of a low voltage circuit from a step-down transformer. The heat of the filament reaches about 1800° C. To this filament is also attached the negative phase of the high tension circuit. The filament is spoken of as the cathode and in operation is negatively charged. Opposite to the filament, and in a straight line with it, is the target, which is made of heavy tungsten and the face is angulated at 45 degrees. It is called the anode and is the positive electrode of the high voltage circuit. The two side arms provide distance between the high tension terminals outside the tube in order to prevent spark over between the terminals. The tube just described is an air cooled superficial therapy tube in common use among dermatologists in the United States.

Perhaps to understand the operations of an *x*-ray tube, it is well to describe what takes place in a two element electrode tube. The principle of thermionic emission or of rectification in a valve tube is similar.

Take a tube which is evacuated and has in it a filament heated by battery A to incandescence. This heated filament will emit electrons. These electrons will remain in the vicinity of the filament if nothing attracts them. Now if a metal plate called a grid is attached to the positive terminal of battery B, the electrons will flow from filament to grid. This is based on the principle that unlike charges attract each other. Thus is established a current of electricity. If the grid is connected to the negative terminal of battery B, there will be no flow of electricity and the galvanometer will not register. Fig. 26 serves to clarify the principle of thermionic emission.

In an *x*-ray tube the low tension circuit heats the filament in a vacuum, thus supplying electrons. The high tension circuit supplies

* In the last edition this chapter was revised by Dr. Edith H Quimby Some of the material added by Dr Quimby has been retained in this edition.

the potential difference needed to drive the electrons to the anode The higher the voltage, the greater will be the speed with which the

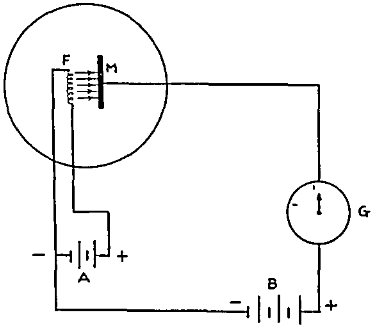


FIG 26 —Two element electrode tube F Filament and M grid are enclosed in a vacuum bulb G galvanometer A A battery to heat filament in order to supply electrons B B battery whose positive pole is connected to grid making possible the flow of electrons from the filament to the grid

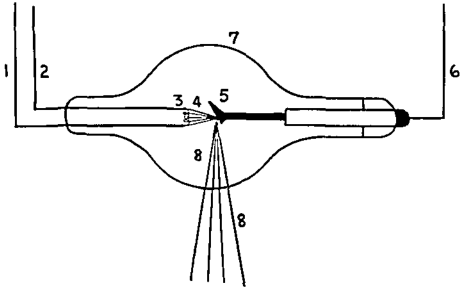


FIG 27 —Schematic drawing of a Coolidge X ray Tube *1* Low tension lead *2* high tension lead *3* filament (cathode) *4* cathode stream *5* anode (target) *6* high tension lead *7* glass wall of *x* ray tube *8* *x* rays within and outside the tube

electrons travel, the stronger will be the impact against the target, and the harder will be the *x*-rays emitted The electrons, in moving from the cathode to the anode, form the cathode stream X-rays

are formed when the electrons strike the target and are deflected from it. Some x-rays are so soft (long wave length x-rays) that they are incapable of penetrating the glass wall of the tube. Thus, the tube itself acts as a filter. Others are so penetrating, depending upon the voltage, that they are capable of penetrating several inches of lead

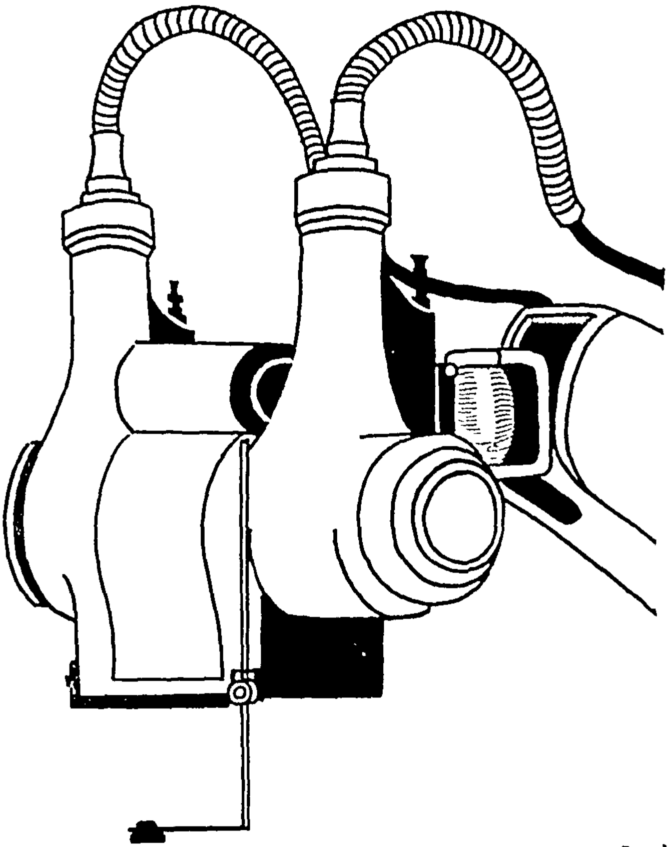


FIG 28 —The head of modern shockproof apparatus showing flexible shockproof cables, the complete enclosure of the x-ray tube in a housing which is shockproof and x-ray proof There is also a device for centering and measuring the distance of the target to the skin surface

Most modern x-ray equipment supply shockproof installations and tubes. The tubes are enclosed in metal housings. Some means of cooling are provided. The most satisfactory appears to be oil-immersed tubes with circulating cold water used to cool the oil. The oil is also a good insulator. Shockproof housings not only supply electrical protection to the patient and operator but also limit the amount of scattered radiations. The only x-rays emitted from the apparatus are those that come through the window of the housing. In most instances the housing is practically x-ray proof.

For routine dermatologic therapy, the 20 and 30 degree angle anode tubes are undesirable because they do not give, at short working distance, a uniform field of x-ray distribution. The point focus, 45 degree angle target, such as open Coolidge tubes, are most desirable,

especially in treating large surfaces of the body in utilizing the overlap principle of irradiation, in temporarily epilating the scalp for tinea capitis

Grenz Ray Tube.—The Grenz ray tube is designed to emit radiation of very long wave lengths Therefore, the tube is to be made of extremely thin glass, or a special window of the Lindemann type has to be provided Ordinary pyrex glass will absorb all x-rays generated within the tube These extremely soft x rays are generated with about 10 kv

Chaoul Tube.—The Chaoul tube, used with voltages of about 50 kv., introduces a new feature in tube designing The important feature of this tube is the anode end The electrons pass down a grounded metal cylinder and strike at its end the target, which is made of gold-plated nickel 0 15 mm thick A water jacket 2 mm thick cools the tube The x-rays penetrate easily the thin target and layer of water Cones of different sizes and shapes fit over the end of the tube and serve to measure distance and protect surrounding normal tissue The working distance is only a few centimeters

Cathode Rays.—The cathode rays are the electrons, which, apparently proceeding from the cathode, produce x-rays by their bombardment of the anode (In some gas tubes a separate "anti-cathode" is provided for this purpose) Their path is the bluish pencil of light proceeding from the cathode They are themselves invisible, but by their bombardment they render faintly fluorescent the molecules of gas in their path The glass wall of the tube fluoresces brilliantly where they impinge upon it and they produce similar effects on many substances placed within their path They are readily deflected by an electric or magnetic field They possess a very powerful photographic action They travel with a velocity which depends only upon the potential difference between the electrodes Only a very small percentage of their energy is transformed into x-rays, the rest being wasted as heat Targets of platinum, and even of tungsten (melting point, 3000° C) can be melted and volatilized in a vacuum tube by this bombardment

If cathode rays are allowed to pass through an opening in the anode, and some device is provided for getting them outside of the tube (such as a window of very thin aluminum foil), their biological effects can be studied

Cathode rays are identical with the beta rays from radioactive substances the only difference being one of velocity The rays from an ordinary (200 kv) x ray tube can penetrate only a few centimeters in air but with recently developed generators capable of delivering 2 or 3 million volts, cathode rays have been produced which travel many centimeters in air, and can penetrate several millimeters into organic matter It is possible that such rays may be employed in the treatment of the more superficial cutaneous diseases At present, however, little study has been made of their biological effects

X-RAYS.

Nature of X-rays.—The x-rays, as we have seen, are electromagnetic waves of very short wave lengths. They are produced by the sudden arrest of the cathode rays at the anode or target of the x-ray tube. They travel in straight lines, with the velocity of light, and are not deflected by the influence of an electric or magnetic field. X-rays are invisible; they are powerful ionizers; they have a strong photographic action and are capable of producing a marked fluorescence in certain chemicals, such as barium platinocyanide. A beam of x-rays, like visible light, is not homogeneous; that is, it is composed of a mixture of waves of different lengths. As in the case of visible light, it is possible to separate these various wave lengths and to study the characteristics of each one. In the case of visible light, we can recognize to a certain degree the various wave lengths by the impression which they make on the eye, namely, the different colors. The wave lengths of the x-rays are too short to register in this manner, hence they are invisible. On account of the extreme shortness of the wave lengths, they cannot readily be separated in the same manner as those of light, namely, by prisms or gratings. But in crystals we have an arrangement of atoms in planes which is the equivalent of an exceedingly fine-lined diffraction grating. It is by this means that the x-ray spectrum is obtained.

It is difficult to obtain by process of comparison or visualization any conception of the size of a short electromagnetic wave such, for instance, as that of the x-rays. For this purpose Shearer states that "it is customary in physics to select such units of measurement as will avoid the use of very small fractions or of very large numbers. Thus the micron, or $\frac{1}{1000}$ millimeter, is used as a unit in microscopy. An average hair is about 20 microns in diameter. In measuring wave lengths of light the Ångstrom or $\frac{1}{100,000,000}$ cm. is usually chosen as a unit. The wave length of yellow light from sodium vapor is about 6000 of these units, while roentgen-ray wave lengths would be expressed by fractions of an Ångstrom Thus we have the diameter of a hair, 0.002 cm , wave length of yellow light, 0.0006 cm., medium roentgen-ray wave length, 0 000000005 cm. Multiplying these fractions by 10 nine times, we have: roentgen-ray wave length, 5; yellow light wave length, 60,000; diameter of hair, 2,000,000. So that the hair could contain 400,000 of these roentgen-ray wave lengths in its own diameter. It is, then, clear that these waves are of exceeding 'fineness of grain' if we may use a common term. The distance between atoms in crystals of metals is from 2 to 4 Ångstroms, so that such atoms are separated by a distance equal to several wave lengths of roentgen rays, such as are commonly used. It may readily be seen how the behavior of such waves would be differently affected by matter than would that of long ones"

The penetration of x-rays into matter is determined by their wave

length and by the density and atomic number of the matter traversed The shorter the wave length, the harder the x-ray, the greater the penetrating power The spectrum of the radiation from an x-ray tube shows a great range in wave lengths The shortest, or most penetrating, the *minimum wave length*, is determined by the potential difference between the electrodes It may be calculated by the formula

$$\text{Wave length (in Ångstroms)} = \frac{12\,354}{\text{kilovolts}}$$

The longest or least penetrating, the *maximum wave length*, is that which can just emerge through the walls of the x-ray tube The relationship of the type of roentgen radiation commonly used in therapy to the voltage and average wave length is given in the following table

Type of radiation	Voltage at x ray tube in kilovolts	Average wave length in Angströms
Grenz ray therapy	10	2 0
Contact therapy	50	0 8
Superficial therapy	100	0 5
Deep therapy	200	0 14
Supervoltage therapy	1000	0 03

It might be supposed that, if a constant potential difference accelerated the electrons from a hot filament, they would all travel with the same velocity, strike the target with the same force, and generate

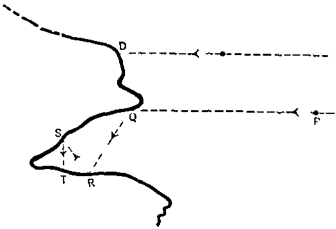


FIG 29 —Diagram illustrating impacts of electron on target *D* direct impact resulting in generation of single x ray of maximum energy *P-Q-R-S-T* multiple impacts resulting in generation of several x rays of relatively small energy

x rays of the same wave length This would be true if the surface of the target were actually smooth and every electron struck in exactly the same way A simple illustration by Shearer shows what may actually happen The heavy line in Fig 29 represents the enormously magnified surface of the polished tungsten target Imagine an electron striking the rough surface at Q Its speed will be somewhat altered

by this impact, and it may be deflected to R and then to S, etc. At each impact, or change of velocity, an x-ray will be originated. Thus a group of these rays may be started by a single electron. On the other hand, direct impact, with resultant complete stoppage, as at D would set up a wave of greater energy for the same initial electron speed. The irregularities of a highly polished metal surface are doubtless much greater than those shown, in comparison with the diameter of an electron.

It is evident from the foregoing that the nature and quantity of x-rays emitted by a given tube are absolutely fixed by the number of electrons used per second and their striking speed The methods for measuring and controlling these factors will be discussed in detail in subsequent chapters

As will be seen, the various types of radiations emitted in a discharge tube are exactly like those emitted spontaneously by radioactive elements. These natural radiations will be described in the next chapter. The passage of radiations through matter, the secondary radiations produced in the process, and the final absorption of the radiant energy will then be discussed for naturally and artificially generated rays together.

BIBLIOGRAPHY.

ANDRADE, E N. DA C · The Structure of the Atom, London, G Bell & Sons, 1923
COOLIDGE, W. D., and CHARLTON, E E Roentgen Ray Tubes, in Glasser O ed, Science of Radiology, Springfield Ill, Charles C Thomas, 1933
DUFF, A WILMER, and others. A Text Book of Physics, Philadelphia, P. Blakiston's Son & Co Various editions
GILBERT, N. E: Electricity and Magnetism Rev. ed, New York, The Macmillan Company, 1941.
GLASSER, O., QUIMBY, E, TAYLOR, L, and WEATHERWAX, J. Physical Foundations of Radiology, New York, Paul B Hoeber, Inc, 1944
MACKEE, G. M., CIPOLLARO, A. C, and MUTSCHELLER, A: Shock-proof Roentgen Ray Apparatus in Dermatology, Arch. Dermat and Syph, 47, 43, 1943
MCNIFF, WILLIAM T.: College Physics, 3rd ed, New York, Fordham University Press, 1942.
MILLER, CARL W.: Introduction to Physical Science, 2d ed, New York, John Wiley & Sons, 1935
ROBERTSON, JOHN K.: Radiology Physics, New York, D Van Nostrand Company, Inc, 1941.

CHAPTER VI

THE RADIOACTIVE ELEMENTS AND THEIR RADIATIONS *

RADIOACTIVITY

By radioactivity is meant that property possessed by certain elements, whereby their atoms spontaneously undergo a special form of atomic disintegration, with emission of penetrating radiations capable of affecting photographic plates, discharging electrified bodies, and producing various chemical and biological phenomena At present about forty such elements are known the most familiar being uranium, radium, radon (radium emanation), polonium, thorium, mesothorium, and actinium While our interest centers mainly in radium it is advisable to consider briefly the different "families" of these substances and thereby to show the relationship of these elements

Types of Radiations —There are three types of rays called alpha, beta and gamma rays Those which are stopped by a sheet of paper are the *alpha rays* They are in reality but helium nuclei traveling at speeds of 9000 to 20 000 miles per second For this reason they are often referred to more appropriately, as alpha *particles* They carry double positive charges (See Fig 2, page 24) In passing through matter these particles are quickly slowed down by colliding with atoms, annex two electrons, and become indistinguishable from helium atoms Since all the alpha particles from a given substance start with the same velocity they all travel the same distance, or are said to have the same *range* This range varies in air from 2 7 cm for uranium alpha particles to 8 6 cm for those from thorium C′ None can pass through a sheet of foolscap paper

The *beta rays* are also particles they are actually electrons, traveling at high speeds Unlike the alpha particles, the beta rays from a given substance vary considerably in speed some of them reaching almost the velocity of light Their mass is much less than that of the alpha particles and they travel much faster Accordingly, they can penetrate much farther into matter before their energy is reduced to the point where they can no longer be distinguished from ordinary electrons The swifter ones can traverse 1 cm of tissue All are stopped by 2 mm of brass or 0 5 mm of gold or platinum

* In the last edition this chapter was revised by Dr Edith H Quimby Some of the material added by Dr Quimby has been retained in this edition

The *gamma rays* are electromagnetic in the same sense as x-rays or visible light. They are of very high frequency, or short wave length, and therefore carry large quanta of energy. They are very penetrating, the hardest passing readily through 25 cm. of lead.

Since electrically charged particles are affected by a magnetic field, the three types of rays may be separated by passing the beam between the poles of a fairly powerful magnet. The gamma rays, since they carry no charge, will go straight through. The alpha and beta particles, having charges of opposite sign, will be deflected in opposite directions. The beta particles, being lighter, will be more easily influenced, and so will be deflected much farther from their original path. (Fig. 30.) It is simpler to get rid of alpha rays by putting a thin layer of matter in their path, but when a pure gamma ray beam is desired in experimental work a magnet is often used to remove the beta particles This method would not be practicable in therapy because of the cumbersome apparatus, and, as we shall see later, is not necessary

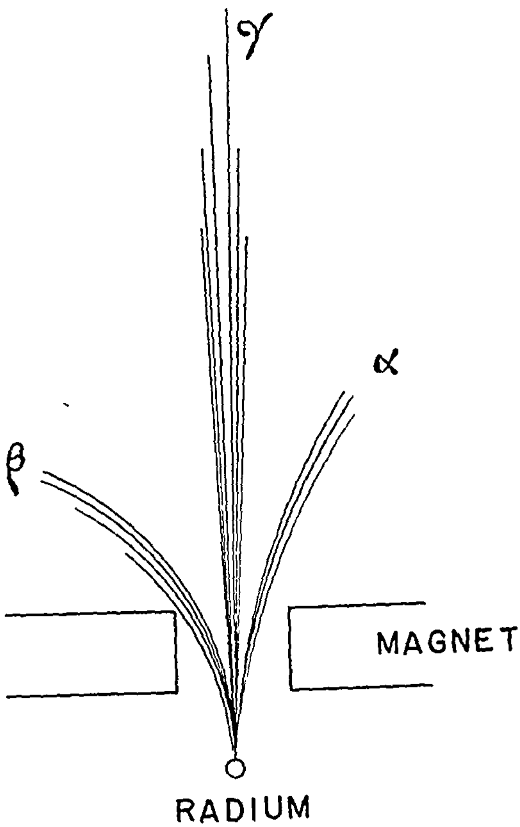


FIG 30 —Deflection of radium rays in magnetic field

Origin of the Rays.—Questions immediately arise as to where the rays come from, why some substances emit them while others do not, why some substances emit one type of rays and others another, and what happens to the substance after it has given out this energy in the form of radiation If it be recalled that, according to the theory of atomic structure, all atoms contain within themselves both positive and negative particles, the answers to these questions will appear

The forces holding together these nuclear aggregates of particles must be very complicated Protons repel each other and electrons do likewise, but protons and electrons attract each other There are also electrical and gravitational forces All these forces of attraction and repulsion must be properly balanced, otherwise the atoms would not be stable enough to be identified. In the uranium atom, with atomic number 92, and atomic weight 238, containing 92 protons, 146 neutrons, and 92 extranuclear or orbital electrons, the maximum complexity is

reached No atom with a larger number of electrons or protons is known to exist in Nature and, in fact, uranium itself is not entirely stable, for occasionally a uranium atom breaks down spontaneously into more simple atoms

All elements with atomic weights larger than 208 exhibit this property of spontaneous disintegration Evidently the larger number of protons and electrons in the atomic system is partly responsible for the relative instability of the atoms but is is not the sole cause The structural arrangement of the component parts has considerable influence also For this reason some elements with atomic weights lower than uranium are much more unstable This instability manifests itself in the sudden explosive change of one atom into another of less complexity During this change, positive or negative particles are ejected from the nucleus, and energy is liberated in the form of electromagnetic radiation A radioactive element is gradually and constantly changing of its own accord irrespective of its environment It should be noted however, that the gradual change is due to the sudden explosion of a certain percentage of the atoms every instant This rate of change is different for different substances but is constant for, and characteristic of, each radioactive element No means has ever yet been found of accelerating or retarding this characteristic rate

Radioactive Series —Careful study of the radioactive elements, of which about forty are known has shown certain genealogical relations among them, which have led to their classification in three series the uranium the thorium, and the actinium series the last being really a branch of the uranium series

The *uranium series* is for our purposes the most important, since one of its members is radium and part of it will be discussed later somewhat in detail It is given in Table 7

The *actinium series* is really a side chain of the uranium series, originating in an abnormal disintegration of uranium II Whereas 97 per cent of this element changes into ionium and proceeds through the uranium series the remaining 3 per cent becomes uranium Y and follows a different series This series is given in Table 8 No element in it is of any practical importance

The thorium series given in Table 9, is relatively more important than the actinium series although its members are of decidedly less practical value than those of the uranium series

Occurrence of Radioactive Substances in Nature —Little is known relative to the formation of the primary radioactive elements From the standpoint of the present-day hypothesis of the structure of matter it seems probable that complicated atoms must have been synthesized under conditions of extremely high temperature such as exist for example in some of the nebulæ

Radioactive substances are widely distributed in Nature The first radium was produced from pitchblende deposits of Bohemia For several years the greater part of the world s radium supply was

TABLE 7.—THE URANIUM SERIES OF RADIOACTIVE ELEMENTS

Element	Atomic weight	Atomic No	Type of radiation	Time of half decay	Equilibrium amount Grams
Uranium I	238	92	Alpha	4.4×10^{9} yr	2.94×10^{6}
Uranium X	234	90	Beta Gamma	24.6 da	4.4×10^{-5}
Uranium X_2 (99.65%)	234	91	Beta Gamma	68.4 sec	5×10^{-10}
Uranium Z (0.35%)	234	91	Beta Gamma	6.7 hr.	6×10^{-10}
Uranium II	234	92	Alpha	3×10^{5} yr	200
Ionium (97%)	230	90	Alpha	83,000 yr	52.7
Radium	226	88	Alpha	1590 yr	1.00
Radon	222	86	Alpha	3.824 da	6.47×10^{-6}
Radium A	218	84	Alpha	3.05 min	3.52×10^{-9}
Radium B	214	83	Beta Gamma	26.8 min	3.04×10^{-8}
Radium C	214	83	Alpha Beta Gamma	19.7 min	2.23×10^{-8}
Radium C′ (99.96%)	214	84	Alpha	10^{-6} sec	2×10^{-19}
Radium C″ (0.04%)	210	81	Beta Gamma	1.32 min	6×10^{-12}
Radium D	210	82	Beta Gamma	22 yr	0.0128
Radium E	210	84	Beta Gamma	4.9 da	7.9×10^{-6}
Radium F (polonium)	210	84	Alpha	140 da	0.000224
Radium G (uranium lead)	206	82		Stable	

TABLE 8.—THE ACTINIUM SERIES OF RADIOACTIVE ELEMENTS

Element	Atomic weight	Atomic No	Type of radiation	Time of half decay	Equilibrium amount Grams
Uranium Y (3% from uranium II)	231	90	Beta Gamma	24.6 da	0.00019
Protactinium	231	91	Alpha	32,000 yr	0.62
Actinium	227	89	Beta Gamma	13.5 yr	0.00025
Radioactinium	227	90	Alpha	18.9 da	9.8×10^{-7}
Actinium X	223	88	Alpha	11.2 da	5.8×10^{-7}
Actinon	219	86	Alpha	3.92 sec	2.3×10^{-12}
Actinium A	215	84	Alpha	0.002 sec	1.14×10^{-15}
Actinium B	211	82	Beta Gamma	36 min	1.21×10^{-9}
Actinium C	211	83	Alpha Beta Gamma	2.16 min	7.2×10^{-11}
Actinium C′ (0.32%)	211	84	Alpha	0.005 sec	2×10^{-18}
Actinium C″ (99.68%)	207	81	Beta Gamma	4.76 min	1.57×10^{-10}
Actinium D (actinium lead)	207	82		Stable	

produced from rather low-grade carnotite ores in Colorado and Utah. Since 1923 most of the radium produced has been refined in Belgium from a very rich pitchblende ore found in the Belgian Congo. More recently, very valuable deposits have been found in northern Canada. It is estimated that over 400 grams of radium have been prepared and sold up to the present time.

TABLE 9.—THE THORIUM SERIES OF RADIOACTIVE ELEMENTS

Element	Atomic weight	Atomic No.	Type of radiation	Time of half decay	Equilibrium amount, Grams
Thorium	232	90	Alpha	1.8×10^{10} yr	1.00
Mesothorium I	228	88	Beta, Gamma	6.7 yr	4.68×10^{-10}
Mesothorium II	228	89	Beta, Gamma	6.13 hr	3.88×10^{-14}
Radiothorium	228	90	Alpha	1.90 yr	1.35×10^{-10}
Thorium X	224	88	Alpha	3.64 days	5.41×10^{-13}
Thoron	220	86	Alpha	54.5 sec	9.23×10^{-17}
Thorium A	216	84	Alpha	0.14 sec	2.32×10^{-19}
Thorium B	212	82	Beta, Gamma	10.6 hr	6.23×10^{-14}
Thorium C	212	83	Alpha, Beta, Gamma	60.5 min	5.92×10^{-15}
Thorium C′ (65%)	212	84	Alpha	10^{-11} sec	10^{-27}
Thorium C″ (35%)	208	81	Beta, Gamma	3.1 min	10^{-16}
Thorium D (thorium lead)	208	82		Stable	

Traces of radioactivity have been noted in sea-water, river waters, spring waters, volcanic rocks, earth, air, etc. In fact, there are very few places where a trace of radioactivity cannot be demonstrated. A minute quantity is found in organic tissues.

On account of the radioactive content (usually radon) of certain natural springs, these waters have been extensively advocated in the treatment of various chronic diseases. Some of these waters are fairly potent, but, as a matter of fact, no obvious relation has been demonstrated between the amount of radon found and the potency of the water from the point of view of the spa treatment, some of the most celebrated spas having the lowest recorded radon contents. The radon contents of these natural waters range from 1 to 100 mc. per 1,000,000 liters. (The millicurie is the amount of radon which will produce the same gamma-ray effect as 1 mg. of radium. These units will be discussed later. It is evident, however, that the actual amount of radon in the waters is very small.)

Radioactive Disintegration.—Each of these radioactive series represents a definite family relationship. Every member of each group is an element from the chemical point of view. It has a definite atomic weight, and it reacts as an element to form compounds. Each element

preserves its identity as long as it lasts But at some time or other, every atom of any given substance will spontaneously disintegrate, with the emission of some type of radiation, and form an atom of the next substance in the series It is impossible to predict how long a specified atom will exist as a given element, it may last only a few seconds or it may endure for millions of years.

Two types of disintegration occur In one, an alpha particle is ejected Since this particle is a helium nucleus, with an atomic weight of 4, the new product will have an atomic weight 4 less than that of its parent. In the helium nucleus are two electrons In order for the new atom to be electrically neutral, two orbital electrons must be dropped at the same time Therefore the atomic number of the new substance will be 2 less than that of its parent In the other type of disintegration, a beta particle is ejected, and this is always accompanied by gamma rays. It is believed at the present time that the nucleus does not contain free electrons, but that the nuclear electrons are combined with protons to form neutrons. The emission of a beta particle implies the breaking up of a neutron into its components and the ejection of the electron. The beta particle having practically no weight, the new product has the same atomic weight as the parent Since no positive charge is lost, it becomes necessary for the new atom to annex an orbital electron to maintain its electrical neutrality, hence it has an atomic number one greater than that of its parent These relations may be followed in the tables

Radioactive Constants.—While it is impossible to predict the behavior of the individual atoms, it is possible to make some statistical studies on their lives These statistical results bear the same relation to the individual atoms that the results of mortality studies do to the lives of individual human beings

In this way it has been found that the number of atoms of any radioactive substance which disintegrate in any given time is always a fixed percentage of the number of atoms present For example, in any preparation of radon, 16.6 per cent of all the atoms present will have disintegrated at the end of twenty-four hours, whether the preparation is new and relatively strong, or old and relatively weak Another way of looking at the same fact is to state that for any radioactive element it always takes a fixed time for a given specimen to decay to one-half its value When it is one-half gone it will take another equal period to reduce this half to one-half of its value, or one-fourth of the original, and so on Thus the half period for radium is 1590 years, for radon 3 824 days, and so on These *half-value periods* are, then, definitely characteristic of the various elements They are given in the tables, where it is seen that they vary between a very small fraction of a second and several billion years As will be seen, they are definitely related to other radioactive constants

Instead of the half-value period, sometimes the *average life* is considered This is a factor which might be considered as analogous to

the average expectancy of life of a human being It represents a statistical average of all the lives of the atoms The method of finding its value may be illustrated with radon The amount of radiation emitted by 1 mc of radon during the first hour of its life may be represented by 1 mc-hr At the beginning of its second hour, it has lost approximately 1 per cent of its initial activity, so that for this hour its radiation would be represented by 0.99 mc-hr If this process be carried throughout the active life of 1 mc of radon, it is found that the sum of all these hourly radiations amounts to 133 mc-hr This is equivalent to $\frac{133}{24} = 5.5$ mc-days So we say that the average life of radon is 5.5 days that is it gives out the same amount of radiation as if it had this life at its full strength instead of a much longer one at a constantly decreasing strength The ratio between the average life and the half value period for radon is $\frac{5.5}{3.824} = 1.43$ The same ratio is found between these constants for all radioactive elements, and it can be shown mathematically that this must be the case

It may be well at this time to call attention to common errors in the interpretation of the half-value period and the average life If one who is not familiar with the subject is told that the half-value period of radon is 3.824 days, he may assume that the second half will disintegrate in another 3.824 days so that at the end of about a week there will be none left Actually after seven days there is still 28.11 per cent of the original amount of radon present Again the statement that the average life of radon is 5.5 days may give rise to the impression that this is the actual life of the average radon preparation, instead of being merely a statistical average for all the atoms in any preparation

The Gaseous Radioactive Elements —In each of the radioactive series there is one transformation product which is gaseous These substances when first identified were called "emanations" However, due to the ease with which the terms emanation and radiation may be confused and in view of the fact that these gases are elements and just as deserving of individual names as any other members of the series the International Committee on Chemical Elements in its 1923 report adopted for them the names radon thoron and actinon, and these terms are now generally used

Radon is the only one of any great practical importance, the others being too short lived to be really useful It is formed in the disintegration of radium An atom of this element, a metal, spontaneously breaks down to form atoms of two gases radon and helium (the alpha particle) Radon is an inert gas a member of the group of so called noble gases," that is, it does not enter into any chemical combination It has an atomic weight of 222 and a half period of 3.824 days It is slightly soluble in water, and some attempt has been made to use these solutions in therapy, but with little success,

since the radon is promptly eliminated through the lungs. In its disintegration it produces only alpha rays, which are themselves of no practical importance. Its great value lies in the fact that it can be easily concentrated into a very small volume, there to produce its decay products, which are very active and give off penetrating radiations.

Active Deposits.—In the early study of radioactive substances it was noted that whenever such materials were placed in a closed vessel, its walls gradually acquired a radioactivity of their own, most of which disappeared rapidly when the radioactive material was removed. This was called the active deposit. We now know that it consists of the disintegration products of the radioactive gases, which, being solids, settle on the walls of the container. The type of transformation for all three gases is the same The gas, chemically inert, is very radioactive. In the case of radon the transformation results in the formation of radium A and helium (the alpha particle).

Radioactive Equilibrium.—As has already been mentioned, enormous differences exist among the half-value periods of the elements of the series. Some are very long and some are extremely short, having no definite relation to the positions occupied in the series. It is, however, no accident that the first members have by far the longest half-value periods The age of the earth is probably millions of millions of years, and any element with a comparatively short life would have completely disintegrated in this length of time It is on account of the long life of uranium and thorium that radioactive substances still exist. The presence of short-lived members subsequent to the first is possible because they are being produced continually. In fact, they are being produced at the same rate at which they disintegrate, and consequently the amounts present remain in the same proportions, as long as the amount of the parent element remains practically unchanged.

This statement can best be demonstrated by an example Consider 1 gram of radium freshly prepared and free from its products of disintegration Since its half-value period is long, it may be assumed that over a period of a few weeks or months it remains constant in amount. In 1 gram of radium there are about 3×10^{21} atoms. In one day about one-millionth of these, or 3×10^{15} atoms will disintegrate to form radon As soon as some atoms of radon are formed, some of them will start to disintegrate at the rate characteristic for the element, one-half in 3 824 days, or 16 6 per cent of those present per day. Hence, at the end of the first day, for every 1000 radon atoms formed, 166 will have disintegrated, leaving a balance of 834. Similarly at the end of each succeeding day, there will be a balance of 834 radon atoms for every 1000 produced during the day But the 834 remaining at end of the first day will also have lost 16 6 per cent at the end of the second, leaving 697. Hence the net result at the end of the second day is 834 + 697, or 1531 for every 2000 atoms produced. This is less than twice the number remaining at the end of the first day. If this process is continued, it will be found that after a certain time

(about thirty days) the amount of radon no longer increases, for the number of new radon atoms formed is equal to the number which disintegrate in the same period of time When this stage is reached radium and radon are said to be in *radioactive equilibrium* The maximum amount of radon which can accumulate from a given quantity of radium is called the equilibrium amount By analogous reasoning it may be shown that there is an equilibrium amount for each member of a radioactive series The equilibrium amount of any radioactive substance in relation to earlier members of the series is the maximum amount which can be found in a given source Since the equilibrium amounts of uranium and radium are 2 910 000 grams and 1 gram and radium is found only as a disintegration product in uranium ores it is evident that the weight of ore required to produce 1 gram of radium must always be in excess of 2 910 000 grams The equilibrium amounts and half value periods of the radioactive elements are directly proportional

Activity or Radioactive Power —By activity is meant the intensity of the electrical ionizing or photographic activity of the radiation from a radioactive substance compared with that from a standard substance—uranium or radium In a radioactive material in which all the elements are in equilibrium the same number of atoms of each member disintegrate per second For each element the intensity of radiation emitted is proportional to the number of atoms disintegrating per second If we disregard the energy differences between the different types of rays we may say that when the substance is in equilibrium the same intensity of radiation is produced by each member of the series although the actual amounts of the various members present will be very different Thus a small amount of one substance may produce approximately the same intensity of radiation as a much larger amount of another hence, *per unit mass* the first emits much larger energy than the second its *activity* is much higher The activity or radioactive power of a given element is inversely proportional to the equilibrium amount or to the half-value period For example from Table 7 it is seen that the equilibrium amounts of radium and radon are 1 and 0 00625 mg respectively Therefore radon is $\frac{1}{0\ 00625}$ = 161 000 times more active than radium

Preeminence of Radium — The uranium series contains many radioactive elements of which radium is only one Why is it then, that radium has been given so much prominence? As a matter of fact it is not because of its own merit but that of its descendants It happens that the several members of the series immediately following radium have short half value periods and so reach equilibrium rapidly That is a short time after radium has been extracted, the equilibrium amounts of radon radium A, B and C will have been formed In a sealed preparation of radium these will remain enclosed with it and their radiations will be attributed to it

It is evident from a consideration of the properties of the three types of rays that the alpha rays can never be of much use therapeutically. Anything which can be stopped by a thin sheet of paper could never get beyond the most superficial layer of tissue. Accordingly, it is only the beta and gamma rays which are of interest from that point of view. A glance at the table shows that neither radium nor its immediate successor, radon, emits anything but alpha particles. If beta and gamma rays are required, the source will have to consist of radium B and C, which, as has just been said, exist in a container of radium which has come to equilibrium with its products. If instead of radium, the container has radon in equilibrium with its products, the radium B and C are there in exactly the same fashion and the same amounts, so the radiations from the two containers are identical. From this point of view, then, it makes no difference which is used The one practical difference is in the length of life of the two. As has been described above, a preparation of radium comes to equilibrium with its products in about a month. After that it loses strength very slowly, being reduced to half in 1590 years. Radon, on the other hand, comes to equilibrium in about three and a half hours, and then proceeds to decay at the rate of half in 3 824 days Thus a tube of radium is practically constant in strength, decreasing only about one-third of 1 per cent per year. Radon decreases at the rate of 16.6 per cent per day.

Since the beta and gamma ray activity of either radium or radon is due to its decay products, tubes of the two, producing the same effects, may be considered radioactively equal. The amount of radon which is thus equivalent to 1 gram of radium is called 1 curie, the amount equivalent to 1 milligram is 1 millicurie. A gram of radium will produce 166 mc of radon daily, but the amount which was 166 mc yesterday is only 138 mc. today, and will be 115 mc tomorrow. Meanwhile, however, today's and tomorrow's supplies will have been collected, and at the end of a month there will be available 1000 mc, the equivalent of 1 gram of radium.

There are arguments for and against each in therapy, not because of any difference in the radiations, for as has just been seen, these are identical With radium the same quantity of material in the same form is always available. No calculating to allow for decay of strength of source is necessary Interstitial irradiation must be done by means of removable implants, whose strengths remain constant throughout the treatment A lost tube or needle is a serious matter financially With radon, the same amount of radioactive material is available as with the equivalent amount of radium, except for occasional accidents, but it is a much more flexible form. Tubes, applicators, or special arrangements can readily be had in any desired strength It is necessary to calculate for the day-by-day decrease, but this is a simple matter. Interstitial irradiation may be by either permanent or removable implants, in either case their strength is constantly diminishing.

Lost radon, financially, means only the loss of the container, and since it is practically impossible to lose radium from a radon plant the insurance becomes negligible It is generally conceded that with 0 5 gram or more of radium, the use of radon is to be preferred, with less, the radon plant and its upkeep are too expensive

Without due consideration one might ask "Why not arrange to take off the radon and use it but have it arranged so that the radium can also be used?" A look at the disintegration table gives the answer It is neither radium nor radon that is being used, but radium B and C If most of the radon is removed from the radium little radium B and C will develop there, and consequently there will not be a useful amount of beta or gamma radiation available in the radium container

Other Useful Radioactive Substances — Although radium and radon are much more widely used than any other radioactive substances mention may be made of a few which find limited use Mesothorium is the most important of these Its rapid decay (half period 6 7 years) makes its production actually more difficult than that of radium but a limited amount has been produced as a by-product in the thorium industry For 3 33 years after its preparation the gamma ray activity of the mesothorium preparation increases, and then it falls gradually at ten years attaining a value equal to that which it had a week after its preparation This complicated decay function (due to the lives of its decay products) makes it important to keep accurate record of its varying strength Commercial mesothorium owes 20 to 25 per cent of its activity to the presence of radium which is isotopic with and inseparable from it It has been employed more extensively in Europe than in America It is extracted only as a by product in the preparation of thorium, it would not pay to refine even very rich thorium ore simply for the mesothorium With the decreasing commercial demand for thorium the supply of mesothorium is therefore becoming smaller

Thorium X preparations, with a half period of 3 64 days which is about the same as that of radon have found some use in the treatment of disease In dermatology they have been used mostly in liquid form for the treatment of telangiectasia and some of the inflammations such as eczema and psoriasis with some success However the method is in the experimental stage it is not free of danger reported successes have not been adequately corroborated and the method has not been popular nor has it been used to any extent in this country Thoron has such a short decay period that it cannot be separated from thorium X and used as is radon

It was the dream of the ancient alchemists to transform ordinary metals into gold Recent developments in nuclear physics indicate the partial fulfillment of this dream It is now possible to transform ordinary metals into new substances by the utilization of the atomic energy Rutherford in 1919 bombarded atoms of nitrogen with alpha

particles (alpha rays of radium). Some of the atoms of nitrogen broke down causing them to eject protons. With the development of supervoltage machines (cyclotrons) it is possible to utilize greater energies than can be obtained from alpha particles. Thus it is possible now to bombard atoms of high atomic weights with greater energies Thus radioactivity can be artificially imparted to practically all metals.

A short summary of the terms used in nuclear physics may help to understand this process better An atom is made up of a nucleus which is positively charged and which makes up the greater mass of the atom. Each atom also contains electrons which carry a negative charge totally equalizing the positive charge of the nucleus Thus an atom is really a complicated structure and each atom is distinguished from another by (1) atomic weight or the number proportional to the mass of the atom, (2) the atomic number or the number of unit positive charges carried by the nucleus. An atom of hydrogen has one electron and the nucleus carries one unit of positive charge. An atom of helium has 2 electrons and the nucleus has 2 units of positive charge An atom of mercury has 80 electrons and the nucleus has 80 units of positive charge. In chemistry the different elements are expressed in symbols, thus, hydrogen is H, helium is He, and mercury is Hg. In modern nuclear physics isotopes of an element are expressed with their atomic weights and atomic numbers. The symbol ${}_1H^1$ represents ordinary hydrogen, ${}_1H^2$ represents heavy hydrogen, ${}_2He^4$ represents helium or an alpha particle, ${}_{80}Hg^{200}$ represents mercury.

An isotope is an element with 2 kinds of atoms of different atomic weights, but with the same chemical properties The atomic number of an element is always the same, but the mass of different atoms in an element may differ—the mass number may be greater or smaller than the atomic weight. Isobars are elements with the same mass number but different atomic numbers.

A neutron is a particle of mass number 1, but without electric charge. They are formed by the bombardment of metals with alpha rays from some radioactive substance Large quantities are emitted as products of nuclear disintegration processes when targets are bombarded by high speed protons, deutrons (heavy hydrogen) and alpha particles Since they have no charge they do not lose energy by ionization and therefore are highly penetrating. As lead is the best means of stopping gamma ray, so materials high in hydrogen content such as water or paraffin wax containing borax, are the best means of stopping neutrons Neutrons produce radioactive products in many substances These substances remain unaltered chemically but have imparted to them by interaction with neutrons artificial radioactivity. Each substance has a different decay period. Radiosodium (${}_{11}Na^{24}$) emits beta and gamma rays and has a half-decay period of 14 8 hours. Radiophosphorus (${}_{15}P^{32}$) emits only beta rays with a half-decay period of 14 3 days Radiocalcium (${}_{20}Ca^{45}$) emits beta and gamma rays

with a half-decay period of 180 days These are just a few examples of the artificial radioactive elements and the duration of their activity These artificial radioisotopes are important because they supplement natural radioactive substances, they can be produced at lower cost they can be used as indicators or traces, they can be injected or ingested and exert their therapeutic effect on the individual pathologic cell The realm of usefulness of these substances will increase as the supply increases and as the biologic experiments increase

Human subjects have been treated with neutrons The reactions on the skin and on tumors of various types are similar to x-rays The erythematogenic properties of neutrons and x-rays are comparable Up to the present the treatments and the results are in the experimental stage Treatments with artificially radioactivated substances have been given to a limited number of patients At present it is impossible to evaluate the therapeutic effects However, it can be said the results thus far are encouraging and perhaps a new era in cancer therapy with artificial radioactive substances is about to be launched The subject of nuclear physics and its use in medicine is fascinating and those who are interested are referred to special articles A few of these are listed in the bibliography

Protection for all exposed to radioisotope and neutron radiations is essential A combination of protective devices is necessary around a cyclotron Thick lead is necessary for protection against x-rays and gamma rays which accompany the bombardment processes in a cyclotron For protection against the neutrons lead is not adequate because neutrons go right through lead Neutron rays are stopped as a result of direct nuclear collisions The best protection is water or paraffin wax containing borax These substances contain large amounts of hydrogen Protection against rays from radioisotopes is the same as that of radium

RADON

Radon or radium emanation is a gas obtained from a radium salt It is an element of atomic weight 222 belonging to the family of rare gases and possessing radioactivity With a suitable emanation plant, radon is collected in capillary tubes and hermetically sealed The original supply of radium salt is preserved practically intact The gas collected contains in addition to radon hydrogen oxygen helium and carbon dioxide but these are removed

When a radium salt is heated or radium chloride in diluted hydrochloric acid is allowed to stand for a time and then boiled, a gas is driven off and is collected in tubes This gas is found to be strongly radioactive For the first 5 hours after collection the radioactivity increases to a maximum Thereafter the radioactivity decreases at the rate of about 16 per cent per day By the end of the fourth day the activity is slightly less than 50 per cent and its activity by the end of the month has almost disappeared The half-decay value of

radon is 3.83 days compared to the half period of radium which is about 1690 years. It follows that the radioactivity of a radium salt does not vary from day to day. For therapeutic purposes the total radiation emitted by 1 millicurie of radon is equivalent to 1 milligram of radium acting for 133 hours It is well to emphasize again that after equilibrium has been established radon emits alpha, beta and gamma rays.

It is important to emphasize this because there have been some articles published pertaining to *radon ointment.* It is claimed that only alpha rays are emitted from this ointment and that it is valuable in the treatment of many superficial and deep lesions of the skin, muscles, nerves, etc. It has been claimed that radon ointment is particularly valuable for the treatment of radiation necrosis and other types of radiodermatitis. We have experimented with radon ointment and have studied the literature carefully. We cannot corroborate the therapeutic claims made for radon ointment. In fact, it is our opinion that some cases of radiation necrosis could be made worse by the application of any agent containing a radioactive substance We therefore do not recommend its use.

BIBLIOGRAPHY

AEBERSOLD, P C., and LAWRENCE, J H Physiological Effects of Neutron Rays, Ann Rev Physiol , 4, 25, 1942

AEBERSOLD, P C Cyclotron Production of Artificial Radioactivity and of Neutrons, LIVINGSTON, M S Neutrons Physical Methods of Measurement, STONE, R S. Neutrons Therapy, all in Glasser, O , ed Medical Physics, Chicago, The Year Book Pushlishers, 1944, p 291, 808, 812

CURIE, M , *et al* The Radioactive Constants as of 1930, Report of the International Radium-Standards Commission, J Am Chem Soc , 53, 2437, 1931

EVANS, ROBLEY D , and LIVINGSTONE, M STANLEY A Correlation of Nuclear Disintegration Processes, Rev Mod Physics, 7, 229, 1935

FAILLA, G., and QUIMBY, EDITH H Radium Physics, in Glasser, O , ed. Science of Radiology, Springfield, Ill , Charles C Thomas, 1933

KENNEY, J M Radioactive Phosphorus as a Therapeutic Agent in Malignant Neoplastic Disease, Cancer Research, 2, 130, 1942

KOVARIK, A F , and MCKEEHAN, L W Radioactivity (Report of the Committee on X-rays and Radioactivity)[8] Bull Nat Res Coun No 51, Washington, 1925

LAWRENCE, J H. The New Nuclear Physics and Medicine, Am Jour Roentgenol , 48, 283, 1942

MILLER, CARL W Introduction to Physical Science, 2d ed , New York, John Wiley & Sons, 1935

RUTHERFORD, ERNEST, CHADWICK, JAMES, and ELLIS, C D Radiations From Radioactive Substances, New York, The Macmillan Company, 1930

STONE, R S , and LARKIN, J C , JR Treatment of Cancer with Fast Neutrons, Radiology, 39, 608, 1942

CHAPTER VII

RADIUM AND RADON APPLICATORS *

There are two general methods of using radioactive substances which may be described as external and interstitial. In the former the radioactive material is contained in an applicator which is placed either on the surface of the body or at some little distance from it; in the latter, it is in needles or other containers for direct implantation into the tissues or body cavities. The two methods do not require completely separate sets of appliances; the needles or tubes used for interstitial irradiation can also be placed in containers and used externally.

Since the beta rays can penetrate only a few millimeters into tissue their only field of usefulness is in the treatment of extremely superficial lesions. In a preparation of radium or radon in equilibrium with its products, the amount of energy delivered in the form of beta rays is many times that delivered in the form of gamma rays. Therefore in *treating any condition which extends to a depth of more than a few* millimeters, it is desirable to eliminate most of the beta rays. Otherwise they would be absorbed in this superficial layer and produce great damage there before enough gamma radiation had been delivered to the deeper layers to produce the effect desired.

Accordingly, the method of application to be used depends on the thickness and location of the lesion to be treated. For extremely superficial conditions, it is well to use as much beta radiation as can be made available. For those slightly thicker but still superficial the very softest beta rays should be removed by a light filter (1 mm Al or 0.5 mm brass),[1] while for anything more than 3 or 4 mm thick it is advisable to use a filter heavy enough to give almost entirely gamma radiation (2 mm brass or 0.5 mm Pt). Also, as the depth of the tissue to be influenced increases the distance of the radium source from the skin should be increased in accordance with the principle discussed in the chapter on Dosage Measurements.

RADIUM ELEMENT CONTAINERS

Permanent radium applicators are supplied by the commercial companies in various forms—needles, small cells, glass or metal tubes, and flat applicators. The content is a radium salt, usually the sulfate,

* In the last edition this chapter was revised by Dr Edith H Quimby. Some of the material added by Dr Quimby has been retained in this edition.

[1] For a discussion of filtration see Chapter VIII.

but the strength is always specified in terms of the amount of radium *element* present, as certified by the United States Bureau of Standards, or some other responsible organization

Plaques.—The term *plaque* has been applied to two entirely different sorts of applicator: (1) A flat applicator, used almost entirely in dermatology, in which a large proportion of the beta rays can be utilized for superficial therapy; and (2) a small box into which tubes or needles can be placed; this is also for superficial therapy, but, in general, the beta rays are eliminated by metal screening

Plaques of the type first mentioned used to be available in three forms. We understand that the glazed and varnished plaques are no longer manufactured. (*a*) *Glazed plaques*, in which the radioactive material has been mixed with enamel and applied to a metal surface, usually silver. The radium is thus very near the active surface, and a large proportion of the beta rays are available. (*b*) *Varnished plaques*, in which the radium is adherent to a silver support, and covered with a coating of varnish or vulcanite. (*c*) *All-metal plaques*, in which the radium on its silver backing is covered by a very thin (0 05 mm.) layer of monel metal. All of these plaques have serious mechanical drawbacks They are fragile; it is difficult to construct containers which are sturdy, and at the same time provide the requisite light filtration It is almost impossible to obtain thin layers of the material used of fixed and uniform thickness, so that the filtration is variable. It is difficult to obtain perfect tightness; if there is a crack or leak, radon escapes and the plaque loses strength. (It is necessary for the radium to be in equilibrium with its products in order for the applicator to have its maximum strength. See Chapter VI.) Enamel plaques may crack under the action of the radium they contain, and varnished plaques deteriorate rapidly with handling. Metal plaques may bulge, with consequent loss of contact with the lesion under treatment. Owing to slight differences in the thickness of the covering material, or of the radium-containing layer, the activity at the surfaces of plaques which are ostensibly the same may vary considerably Therefore, every dermatologist must establish experimentally the skin dose for such plaques as he uses.[1]

In spite of all these drawbacks, plaques are much used in dermatology. They are obtainable in a variety of shapes and sizes. In America three strengths are recognized: half strength, containing 2 5 mg of radium per square centimeter of active surface; full strength, 5 mg. per sq cm , and double strength, 10 mg. per sq. cm. Table 10 shows

[1] Such standardization is best done by determining experimentally the erythema dose for each plaque It is wise to start the tests with a dose believed to be below that which will produce a reaction, and work up gradually Several individuals should be used for the tests since there is some personal variation in the susceptibility to radiation The dose must be determined for the unfiltered plaque, and also for each filter combination which is to be used It is best to determine the dose for various distances

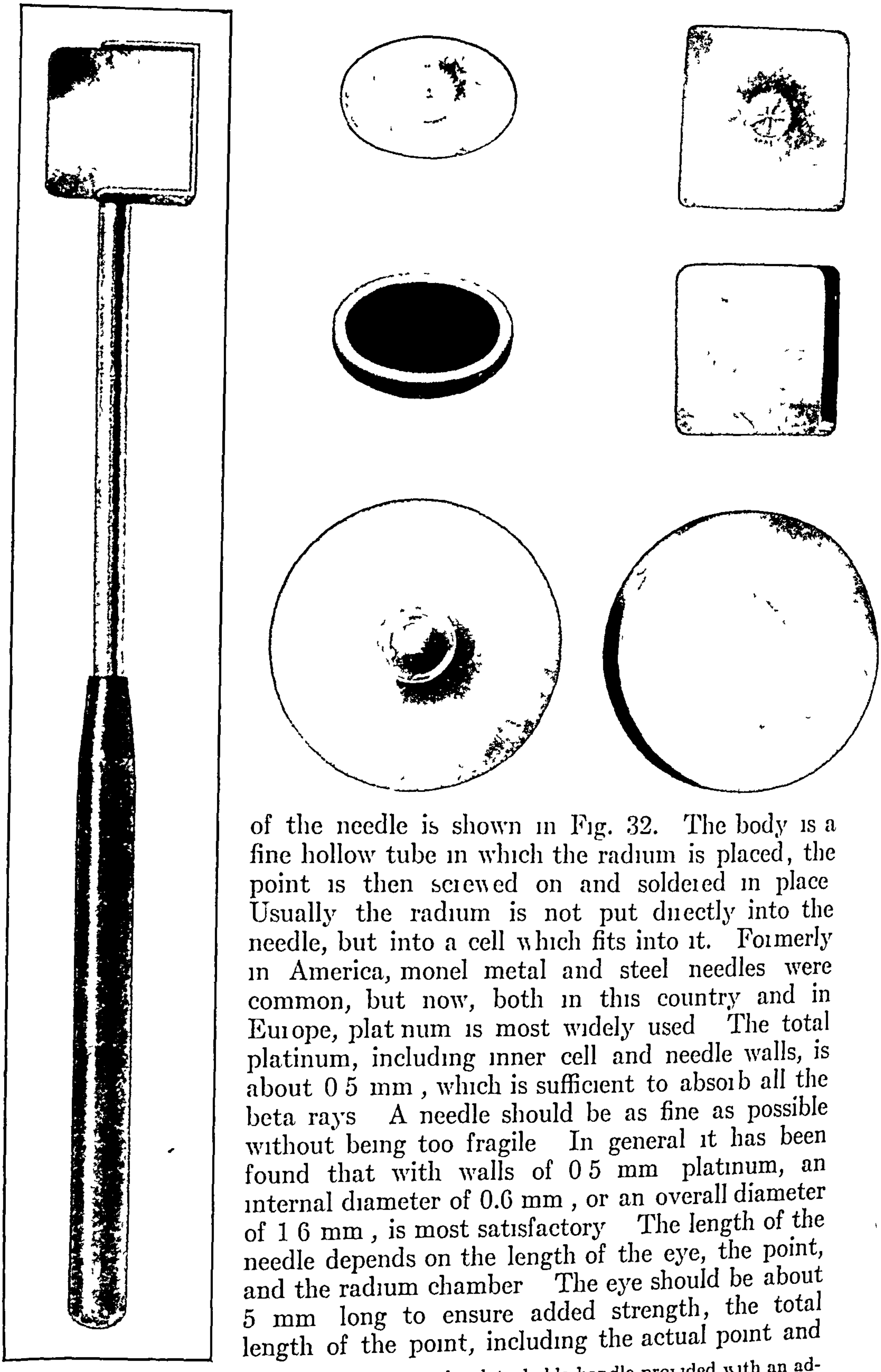
the relative sizes and radium contents of these three types. Photographs of some of them are shown in Fig. 31, together with a detachable handle for them.

TABLE 10.—FLAT RADIUM APPLICATORS—ACTUAL SIZE

Milligrams of radium element	Double strength	Full strength	Half strength
10	1 Sq. Cm.	2 Sq. Cm.	4 Sq. Cm.
20	2 Sq. Cm.	4 Sq. Cm.	8 Sq. Cm.
30	3 Sq. Cm.	6 Sq. Cm.	12 Sq. Cm.

These plaques may be provided with screens to remove part or all of the beta rays. Since the quality of the radiation (relative percentage of beta and gamma rays) varies from one applicator to another, the result to be expected by the addition of a given screen in any case is not specific unless sufficient filter is added to remove all the beta rays, namely 2 mm. of brass or its equivalent. It is probable that the use of a variety of intermediate screens is of no real advantage. One thin aluminum screen (0.1 to 0.2 mm.) for removing the very soft rays and one of 2 mm. of brass to provide a gamma ray source should be sufficient.

Needles.—Needles may either be used in interstitial therapy or enclosed in other containers and used externally. The construction



of the needle is shown in Fig. 32. The body is a fine hollow tube in which the radium is placed, the point is then screwed on and soldered in place Usually the radium is not put directly into the needle, but into a cell which fits into it. Formerly in America, monel metal and steel needles were common, but now, both in this country and in Europe, platinum is most widely used The total platinum, including inner cell and needle walls, is about 0 5 mm , which is sufficient to absorb all the beta rays A needle should be as fine as possible without being too fragile In general it has been found that with walls of 0 5 mm platinum, an internal diameter of 0.6 mm , or an overall diameter of 1 6 mm , is most satisfactory The length of the needle depends on the length of the eye, the point, and the radium chamber The eye should be about 5 mm long to ensure added strength, the total length of the point, including the actual point and

FIG 31 — Glazed and metal plaques, and a detachable handle provided with an adjustable locking-screw joint (Courtesy of Dr W H Cameron and of the Union Minière du Haut Katanga, Brussels, through its distributor, the Radium Chemical Company, Inc , New York)

the screw portion, about 6 5 mm Hence *the total length of the needle is about 11 5 mm more than that of the actual radium-bearing portion*, a fact which is often lost sight of The length of the radium chamber may be whatever is desired If it is more than 25 mm it is advisable to have the radium in two or more cells, to insure reasonably uniform distribution of the radium source in the container

Some radiologists prefer to have all their radium in such removable cells usually very small and of small radium content (1 or 2 mg each) which can be inserted into sheath needles or other containers at will They find this a very flexible and satisfactory arrangement

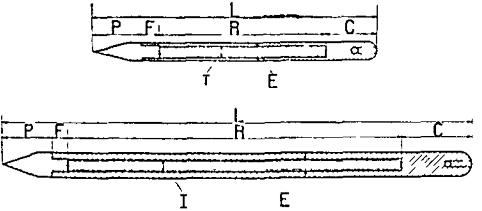


FIG 32 —Diagrams of radium needles *L* total length of needle *R* length of radium chamber *C* length of eye *P* length of point *F* length of screw *E* external diameter *I* internal diameter (Courtesy of the Union Minière du Haut Katanga Brussels through its distributor the Radium Chemical Company Inc New York)

Tubes —Formerly it was customary to supply radium in glass tubes which could be inserted into various metal shields At present the construction of tubes is essentially the same as that of needles—an inner cell of thin platinum in a thicker platinum tube with ends heavier than the side walls Total filtration of 0 5 or 1 mm of platinum is employed in the tube with the possibility of adding screens to this if desired Frequently one end of the tube is furnished with an eye Its diameter and length depend on the radium content and the desire of the purchaser At present tubes of 25 mg or less are more generally used than those of greater radium content since greater flexibility is obtained by having numerous moderately weak sources than a few strong ones

It has already been mentioned that the total length of a radium needle is considerably more than that of the radium bearing portion This is also true of most radium tubes In this case the inactive region may not be approximately the same at both ends but definitely longer at the eye end This fact must not be overlooked when such sources are applied in therapy If it is lost sight of the region of maximum activity may be some millimeters from the point where it is supposed to be

RADON CONTAINERS.

Tubes.—As mentioned in Chapter VI, the radon may be removed from the purifying apparatus in glass or gold capillary tubes of any desired strength. In general, if the sources are not to be used as implants, they are in the form of glass capillary tubes, about 14 mm. long and 0.5 mm. in diameter, which are to be put into metal jackets. At the time of preparation, these tubes contain from 50 to 300 mc. of radon; since they lose activity as discussed previously, a working radon laboratory will have available tubes of a wide range of strengths. The jackets customarily used are of an alloy of gold and platinum, have a wall thickness of 0.5 mm., an overall diameter of 1.6 mm., and a length of 16 mm. The use of such radon tubes is exactly the same as that of radium tubes.

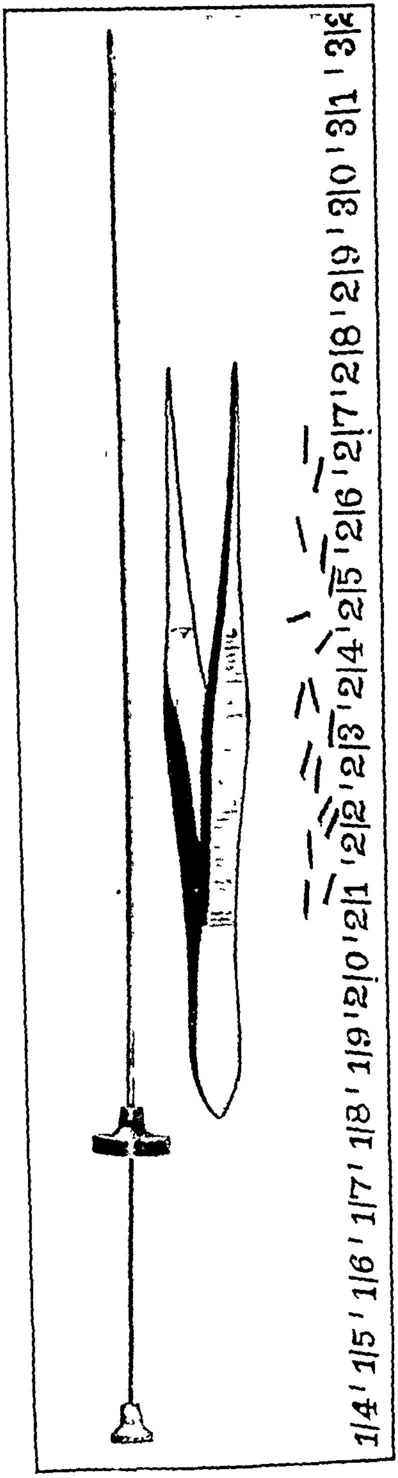


Fig 33 —Gold seeds, forceps and trocar

Seeds.—For interstitial irradiation, very tiny glass tubes, containing about 1 mc of radon, were formerly used. Since these delivered a high percentage of beta rays, considerable necrosis was always produced about them These glass "seeds" have now been practically abandoned in favor of seeds made of fine gold capillary tubing. These are about 4 mm. long, have a wall thickness of 0.3 mm., and an external diameter of 0 75 mm. (If desired they may be made of tubing with any wall thickness from 0 2 to 0 5 mm.) When first prepared they contain about 0 5 to 4 mc. of radon Gold seeds and a trocar for inserting them into the tissue are shown in Fig. 33 The centimeter scale in the figure gives an idea of their actual size Trocars of different shapes and lengths are obtainable.

Removable seeds are sometimes desired, to be used in the same manner as small radium needles. In this case the radon is collected in glass seeds

which are put into tiny platinum jackets. These are inserted with trocar needles as are the gold seeds and later withdrawn by an attached thread or wire.

Needles.—If it is desired to use removable needles, the gold capillary tubing containing the radon may be cut to any desired length and placed in steel sheath needles, bringing the total filtration to the equivalent of 0.5 mm. of platinum. With these sheaths available in a variety of lengths it is possible to have needles of the most satisfactory length and strength for any given lesion.

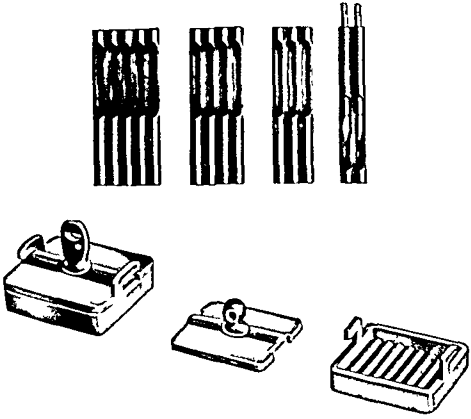


FIG. 34.—Typical radium or radon applicators. (Courtesy of Union Minière du Haut Katanga, Brussels, through its distributor, the Radium Chemical Company, Inc., New York.)

APPLICATORS AND AUXILIARY APPLIANCES

Containers.—For external irradiation radium needles or radium or radon tubes may be placed in a variety of containers of which samples are shown in Fig. 34. The type of applicator to be used in any particular case depends on the size of the lesion and the depth to which it is desired to deliver an effective dose. These questions will be discussed in subsequent chapters.

In the case of lesions on irregularly shaped surfaces, such as the lip or ear, it is often most convenient to make a mould of the part of some plastic material, embed the radium or radon tubes therein and use

Distance Blocks.—When the applicator is to be used at a distance of 0 5 cm. or more, it is essential for satisfactory dosage that this distance be accurately known. An uncertainty of 1 mm in the distance, for a small plaque supposedly at 1 cm. from the skin, means an uncertainty of about 15 per cent in the amount of radiation reaching the skin In order to know the distance accurately, it is necessary that the material used for the supporting block be rigid. The use of such compressible substances as gauze, or of such deformable ones as wax, is to be discouraged Balsa wood is a very satisfactory substance for the purpose Blocks can be readily cut to the desired size, and used repeatedly. They should, however, be discarded when they show signs of wear.

Sterilization of Radium and Radon Tubes and Needles.—Radium and radon tubes, seeds and needles can be sterilized by boiling, unless they are encased in some substance which might be corroded by water (*e g.*, silver). They should not be subjected to dry heat. They can, of course, be sterilized by immersion in alcohol. Needles should, as a matter of routine, be cleansed with benzine or ether upon removal from the tissues, then rinsed in alcohol, and coated with sterile oil All screens and special containers should be kept scrupulously clean

PROTECTION.

The whole subject of protection in relation to x-rays and radium is discussed in Chapter XIV. However, it may be well to make some particular suggestion at this time with respect to the handling of

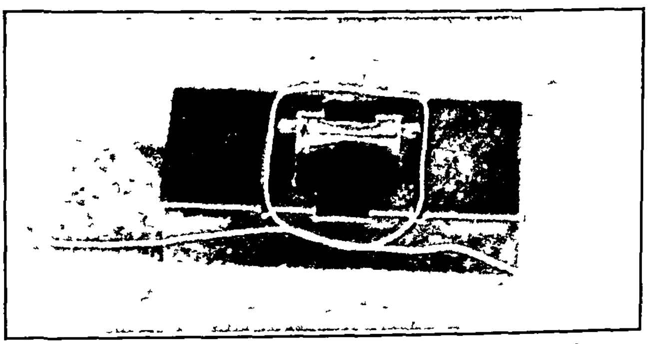


FIG 38 —Illustrating heavy metallic screening block, showing depression cut on one surface This depression must be slightly larger than the applicator and deep enough so that the applicator, with its thickest screen, will be slightly below the surface of the block when placed in position A purse-string suture (heavy cord or silk thread) is arranged as shown (Dr W H Cameron)

radium or radon The first rule in this matter is that *no plaque, tube, or needle containing radium or radon should ever be handled with the fingers.* Forceps should always be used, even for momentary handling of very weak sources. Greater care is necessary with beta ray applicators than with heavily screened sources, because of the relatively greater intensity of the radiation and its greater absorbability in the

superficial tissues For plaques, an easily adjustable handle should be available If it is not, or if, for other reason the plaque is to be

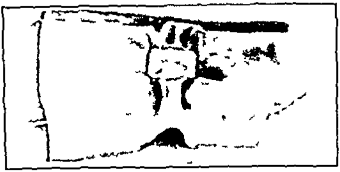


Fig 39 —Thin rubber sheeting cut to size is now placed over the opening and the applicator placed face downward in the depression By pulling on ends of suture the rubber sheeting is puckered on back of applicator The excess rubber is now cut away permitting however the long ends of the string to remain as in Fig 40 (Dr W H Cameron)

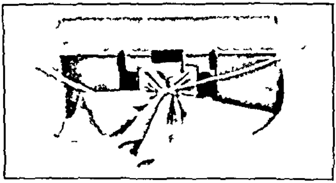


Fig 40

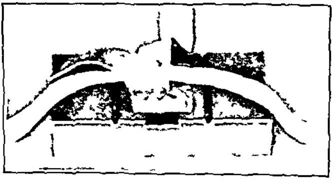


Fig 41 —Illustrating the manner of fixing adhesive plaster to back of applicator by tying in place with ends of suture used to pucker the rubber sheeting (Dr W H Cameron)

used in some other manner, some such scheme should be used as is shown in Figs 38 39 40 and 41 When a plaque is to be used with a distance block the block should be carefully adjusted to the patient

and then the plaque quickly attached to it Needles, while being threaded, should either be held in grasping forceps, or, preferably, placed in a frame which exposes only the eyes A convenient frame for this purpose, which can also be used to hold needles and threads during sterilization, is shown in Fig. 42

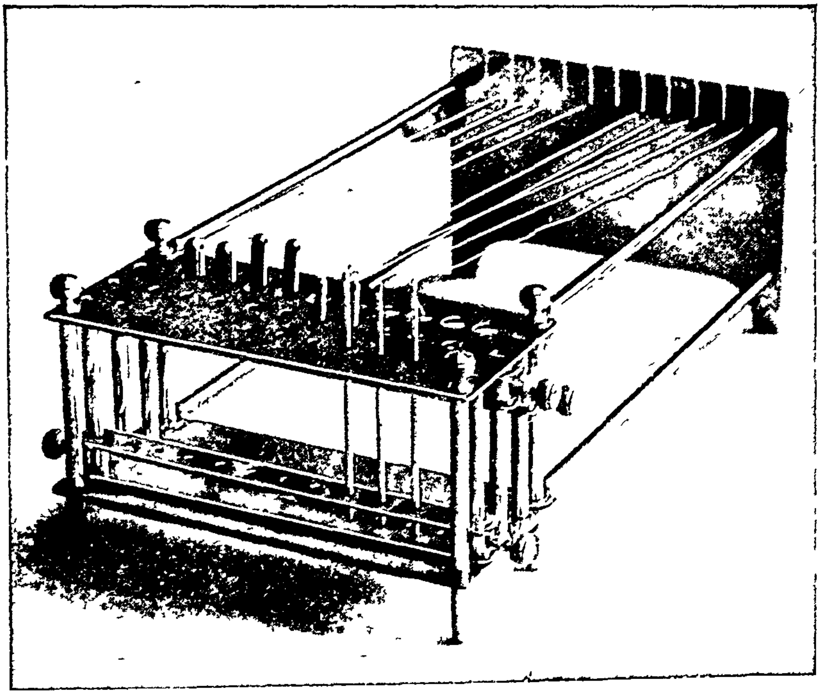


Fig 42 —Sterilizing rack for needles (Courtesy of the Union Minière du Haut Katanga, Brussels, through its distributor, the Radium Chemical Company, Inc , New York)

Various types of forceps, either pick-up or with grasping jaws and locks, for handling different types of containers and applicators, are readily obtainable. If a nurse or technician is to spend more than a few minutes daily handling radium preparations, lead screens should be provided for her protection The size and thickness of these must be determined by the amount of work to be done At least 1 inch of lead is necessary for reasonable protection, 2 inches is to be preferred. Further data along these lines will be found in Chapter XIV.

In general, the nurse or technician should not remain in the room with the patient after the radium has been applied, and should *never* hold it in place If such service is necessary, it should be performed by the patient himself, or by a member of his family. However, it is seldom that an applicator cannot be satisfactorily held in place by mechanical means.

LOSS OF RADIUM OR RADON

Loss of radon is not important from a financial point of view since its value, aside from that of the container, is small Loss of radium, on the other hand is extremely serious, and all possible precautions should be taken to prevent it Routine checking and rechecking of the movements of the radium should be made by responsible persons Patients having radium applied should be closely supervised No dressings from a radium patient should be thrown away until the routine check up shows everything in place

If, in spite of precautions, radium should be missing and not immediately located, no time should be lost in communicating with one of the commercial companies, a hospital physicist, or the physics department of a college or university These institutions have apparatus which can be used to determine the presence of even a small amount of radioactive material in a large volume of trash or ashes But it must be remembered that the sooner the search is started, the greater the likelihood of finding the lost article It is advisable to be insured against the loss or theft of radium

Radium and Radon Dosage —In the treatment of superficial angiomas, keratoses and superficial basal-cell epitheliomas and other lesions the dermatologist often employs a half-strength radium plaque with little or no filtration He utilizes mostly beta rays of radium As yet there is no practical and satisfactory physical method of measuring beta radiation dosage Dosage is based mostly upon biologic measurements The method most commonly used is the erythema dose It has been stated that each plaque has to be tested for the erythema dose, so that for various diseases, fractions or multiples of an erythema dose of beta rays of radium are used

In gamma ray therapy the story is quite different because dosage can be accurately measured in physical units The unit of measurement is the roentgen or better the gamma ray roentgen An erythema dose with gamma rays is equivalent to 1000 r One milligram of radium at a distance of 1 cm filtered through 0 5 mm Pt in 1 hour will deliver 8 5 r With these simple factors it is easy to convert physical measures into erythema effects

It is well to emphasize again that the gamma ray activity is the same with radium as it is with radon provided that the milligrams or the millicuries are the same and all other factors such as distance filter and time are equal Allowances for radioactive decay for radon have to be made A filter of 2 mm brass or 0 5 mm Pt removes all the beta rays Further filtration changes the output but does not alter the quality to an appreciable extent Dosages expressed in milligram or millicurie hours are incomplete Other conditions of treatment, such as distance and filter are important The distribution of the radium or radon in the containers and the shape of the containers also

influence dosage Paterson and Parker have published charts and tables which are generally applicable in surface, as well as interstitial, irradiation. The reader is advised to study these articles

The practical method of interstitial irradiation is by means of radon implants which are left within the tissues permanently. It is obvious that the tissues in direct contact with seeds receive larger doses than tissues removed from the radiation source In attempting to equalize the dose in a mass of tissue, the seeds should be applied not more than 1 cm. from each other. For large flat masses seeds are placed in planes. The distance between planes and needles is between 1 and 1.5 cm. The margins of the mass should have a series of seeds running at right angles to the planes. The edges of the lesions should be well covered by the radiation source. Naturally the shape of the lesion will determine the distribution of the seeds. For a volume of 2 cu. cm., 80 millicurie hours are required to deliver 1000 r For different dosages and for different volumes of tissues to be irradiated the reader is referred to the Paterson and Parker charts. Details of treatments of skin diseases with x-rays, radium or radon will be discussed in the practical chapters of this book

BIBLIOGRAPHY

FRIEDRICH, W Measurement of Gamma Rays, Am Jour Roentgenol, 40, 69, 1938.

GLASSER, O, QUIMBY, E H, TAYLOR, L S, and WEATHERWAX, J L Physical Foundations of Radiology, New York, Paul B. Hoeber, Inc, 1944

GRAY, L H Radiation Dosimetry, Brit Jour Radiol, 10, 721, 1937

QUIMBY, E H. The Specification of Dosage in Radium Therapy, Am Jour Roentgenol., 45, 1, 1941.

PARKER, H N Dosage System for Interstitial Radium Therapy, Brit Jour Radiol, 11, 313, 1938

PATERSON, R, and PARKER, H M Dosage System for Gamma Ray Therapy, Brit Jour Radiol, 7, 592, 1934

CHAPTER VIII

THE PASSAGE OF RADIATIONS THROUGH MATTER *

ALTHOUGH the methods of production of x rays and radium rays are so different, the actual radiations may well be studied together, for they all possess certain properties in common, and they may all be detected and controlled in similar ways

These radiations manifest themselves in a number of phenomena, including the production of fluorescence in certain substances, the darkening of photographic film, the effecting of other chemical changes and the generation of heat in any substance bombarded by them, Most important and probably fundamental to all other effects, is the production of ionization—the separating of molecules or atoms into positively and negatively charged particles All of these effects are interesting and practically all of them have been made use of in one way or another to measure the intensity of the radiations The more important of these methods of measurement will be described in later chapters Biological changes, which are the basis of all radiation therapy doubtless result from chemical changes produced in the living cells, these chemical changes in turn are probably the result of the disturbances of electrical balances

Any change produced in matter must be the result of some expenditure of energy upon it The energy to produce changes attributed to radiation must be in some way absorbed from the rays during their passage through matter Matter, even in the solid state, must be conceived of as consisting of atomic nuclei with their orbital electrons, and interatomic or intermolecular spaces In even very dense matter there is actually considerably more space than substance The manner in which different types of radiations traverse matter, and give up to it some of their energy, may be visualized as follows Alpha particles being relatively heavy and traveling with great speed, will plow fairly straight paths through matter If electrons are in their way, these will be knocked aside However, at each collision with an electron, some of the energy of the alpha particle will be transferred to the electron so that finally the particle will be slowed down to a speed similar to that of the atoms of the material it is traversing It will, of course occasionally happen that an alpha particle collides squarely with another atomic nucleus Such a blow may result in the actual breaking up of the nucleus which means artificial disintegration Investigations of this phenomena are among the most fascinating in modern

* In the last edition this chapter was revised by Dr Edith H Quimby Some of the material added by Dr Quimby has been retained in this edition

physics. Since however, such results are produced by only one alpha particle in several million, they may be ignored as far as any practical consideration is concerned. The knocking away of orbital electrons does not, of course, constitute an atomic transformation, but simply *ionization* The removal of one or more orbital electrons leaves the atom with a net positive charge—it is a positive ion. The electron which has been removed, either alone or together with a neutral particle to which it may have attached itself, is the negative ion While the atoms are in this abnormal condition, various reactions may take place which would not occur under normal conditions Unless the ions are artificially maintained in their charged condition, however, they quickly reunite with others of opposite electrical charge, so that neutral atoms again result.

The passage of a beta particle through matter is similar to that of an alpha particle. However, since the mass is so much less, the path will not be so direct. Whereas when an alpha particle collides with an electron it simply knocks it aside, a beta particle, being identical in mass with the electron, will be deflected from its own path by such an encounter. While following a very tortuous route, it will ionize atoms along its path by removing some of their electrons. Although its path is not so straight as that of the alpha particle, it is much longer, because of the greater initial velocity of the beta ray

C. T. R Wilson has devised a very ingenious method for making visible the actual paths of alpha and beta rays through matter. This depends on the fact that any ion present in air supersaturated with water vapor attracts water molecules to itself, causing them to condense as a fog particle In the Wilson apparatus the passage of an ionizing particle can be followed by fog trails produced in the supersaturated air Photographs of alpha and beta-ray tracks are shown in Fig 43 The alpha ray tracks are very straight and very dense, showing the great number of ions produced as the particle plows its way through the gas The beta-ray paths are very crooked and much fainter, showing the production of fewer ions, and the great ease with which the beta particles are deflected from their paths

It is thus fairly easy to visualize the paths of alpha and beta particles through matter, and the manner in which they gradually lose energy. For gamma rays it is not so simple The mechanism of the transfer of energy between these electromagnetic radiations and matter is very complicated and incompletely understood. This is especially true if the radiations are considered as waves If, however, they are regarded as photons, or particles of energy, the difficulty is not so great Instead of thinking of waves sent out uniformly in all directions, they are to be conceived of as great numbers of discrete units, emitted, as are the other types of particle radiation, at random in all directions Because of their great number, the intensity of the radiation is effectively the same in all directions. These photons all travel with the same speed (that of light), but they possess various

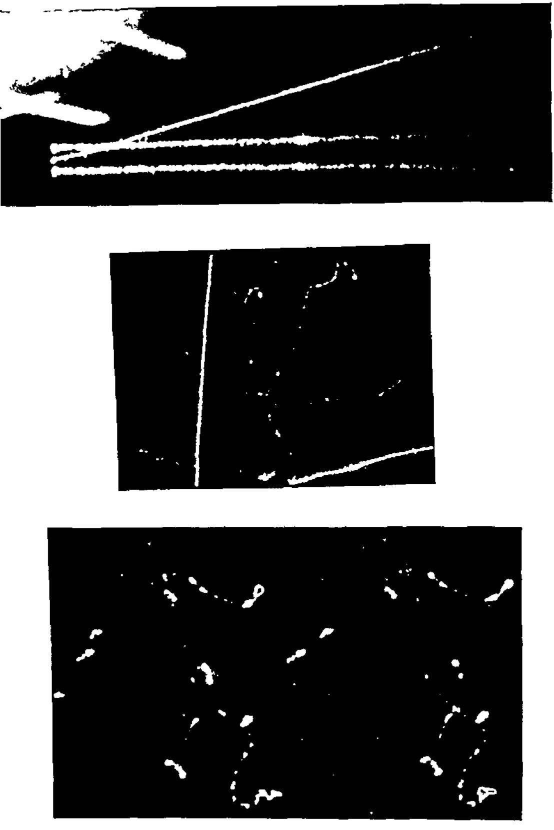


Fig 43 —Wilson cloud chamber photographs of alpha and beta ray tracks (Rutherford Chadwick and Ellis Radiations From Radioactive Substances courtesy of The Macmillan Company and Cambridge University Press)

quanta of energy, depending on their frequency. The passage of the photons through matter may now be considered as analogous to that of beta particles. When one collides with an electron, it may just loosen it from its orbit, as does the beta particle, losing some of its energy in the process. The direction of the photon path is altered, it proceeds as a smaller quantum of energy, strikes another electron, and the process is repeated On the other hand, the photon may give up to the electron practically its whole quantum of energy. In this case the electron will be set in motion with such great velocity that it will be virtually a beta particle itself It will then behave as the primary beta particles which were released from radioactive substances in the first place. In either case, the released electrons act as ionizers, until the energy of the photon is finally completely used up in producing ionization. The Wilson cloud track photograph of x-rays or gamma rays is then really a photograph of the group of beta particles set in motion by the action of the photon.

Secondary Rays.—When x-rays pass through matter, they are partially absorbed; the emergent beam has characteristics quite different from the original beam. These x-rays are referred to as secondary rays There are three types of secondary rays. They are scattered, characteristic and corpuscular rays

Scattered Radiation.—X-rays are scattered in all directions by any kind of matter through which they pass. They may be considered as primary rays but deviated in direction and of longer wave length because in passing through matter the primary rays have given up part of their energy to the filtering substance. This scattering has to be taken into calculation when irradiating a patient. The skin receives the primary beam and the underlying tissues receive in addition the longer wave length scattered rays.

Characteristic Radiation—When a primary ray (a photon) collides with an electron in a K, L, M or N shell of an atom, all of the energy is given over to the electron and is then shot off as a photo-electron. The shells are quickly filled by other electrons and energy is liberated in form of radiations whose wave length is longer than the primary beam. Each metal has its own characteristic radiation. The higher the atomic weight the shorter the wave length of the characteristic ray Thus, characteristic rays are long wave length x-rays The practical significance of characteristic rays is evidenced in utilizing auxiliary filters of lower atomic number (aluminum) to absorb characteristic radiations given off by filters of higher atomic numbers (copper).

Corpuscular Radiation.—When matter is irradiated by roentgen rays, electrons are emitted. There are two types of electrons emitted One group consists of primary photo-electrons with relatively high velocities and the other group consists of recoil electrons which have much lower velocities They may be likened to the cathode stream They are not x-rays However, they are of great importance because

they are responsible for the ionization produced in air and for the action in tissues

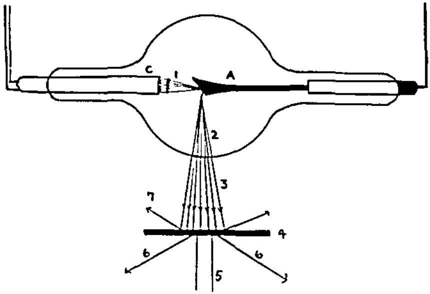


FIG 44 —Schematic diagram of primary and secondary rays 1 Cathode rays 2 primary x rays inside tube 3 primary x rays outside tube 4 filter of high atomic weight 5 primary x ray beam reduced in intensity due to absorption of some of the rays by the filter 6 scattered and characteristic rays going in all direction The characteristic rays are absorbed by the second filter (not shown) of lower atomic weight 7 Beta rays are scattered in all directions C cathode A anode

Absorption —The loss of energy of a beam of radiation in its passage through matter is known as the absorption of the radiation Since the paths of the alpha particles are nearly straight, and practically all the alpha particles from a given radioactive substance have the same speed, a sheet of matter of insufficient thickness for their complete absorption will allow nearly all the particles to pass through, but their speed will be diminished In the case of the beta particles not only will the speed of the emerging particles be less than it was, but also the total number of particles will be less This is due to two causes (1) The initial speed of the beta particles is not the same and some of the slower ones will have lost all their energy in the sheet of matter (2) Some of the particles will have been scattered completely out of the original beam On the whole the loss of speed of the fastest particles is relatively small while the slower ones are readily stopped, and consequently if the material traversed is not too thick, the *average* velocity of the emergent beta particles is higher than that of the incident ones Matter in this case *filters* out the slow speed particles and therefore the filtered radiation is more penetrating But it should be remembered that all the particles are slowed down to some extent

In the case of gamma rays and x-rays, speed has nothing to do with absorption, for all photons travel with the same velocity The con-

trolling factor is the frequency, or the energy of the quantum Photons of relatively small energy quantum, or those whose frequency is small, or those whose wave length is long—all three expressions indicating the same thing—are more readily absorbed The result is that here, as with the beta particles, all the photons are reduced somewhat in their energy, but the relative reduction for those which have little energy to begin with is greater than for the powerful ones Hence the net result of the passage through matter, or *filtration*, is an increase in the average penetration. It must be noted that the penetration of no single photon is increased, as a matter of fact, all are decreased somewhat It is simply that the *average* is raised.

It must also be remembered that any improvement in *quality* or *penetrating power* is at the expense of *quantity or intensity*. After filtration the beam is more penetrating, but it is less intense.

The amount of hardening action produced by a filter depends on its nature and thickness, and the nature of the radiation After traversing sufficient material, radiation of any type loses so much energy that it is softer than the original beam Thus the action of a thin filter may be to harden the radiation, while the addition of still more material may re-soften it

BIBLIOGRAPHY

COMPTON, ARTHUR H , and ALLISON, SAMUEL K *X-rays in Theory and Experiment* New York D Van Nostrand Company, 1935

FAILLA, G , and QUIMBY, EDITH H Radium Physics, in Glasser, O , ed Science of Radiology, Springfield, Ill , Charles C Thomas, 1933

RUTHERFORD, ERNEST, CHADWICK, JAMES, and ELLIS, C D Radiations From Radioactive Substances, New York, The Macmillan Company, 1930

STENSTROM, K W Physics of Roentgen Rays, in Pohle, E , ed , Theoretical Principles of Roentgen Therapy, Philadelphia, Lea & Febiger, 1938

WEBSTER, DAVID L Roentgen Ray Physics, in Glasser, O , ed Science of Radiology, Springfield, Ill , Charles C Thomas, 1933.

WILSON, C T R On an Expansion Apparatus for Making Visible the Tracks of Ionizing Particles in Gases and Some Results Obtained by Its Use, Proc Roy Soc., London, S A , 87, 277, 1912

CHAPTER IX

DEFINITIONS OF QUANTITY AND QUALITY OF RADIATION *

It is evident from the foregoing chapters that radiations differ considerably among themselves. It is not sufficient to specify radium or x rays, since even in a given beam of x rays a variety of radiations exists ranging from very soft or long wave length to hard, short wave length. It is necessary to have some means of specifying the *quality* of the radiation. It is also essential to be able to state how much there is of it or its *quantity*.[1]

The quantity of x-radiation is directly proportional (within limits) to the effect produced and many radiation effects have been recommended as standards for measurement, notably the heat generated, the darkening of photographic film, certain chemical changes and the killing of the eggs of the fruit fly. The most satisfactory, however, is the ionization current produced in a gas.

Various devices are used for measuring this ionization current, some of which will be described in a later chapter. For the present it is sufficient to say that the unit of quantity of radiation is the roentgen. It was established by an international commission.

The Roentgen.—This unit is called the roentgen in honor of the discoverer of x-rays, and is abbreviated as the r, written with a small letter. (The term r unit, frequently heard, is tautological and incorrect.) It is defined as follows: "The roentgen is that quantity of radiation which, when all the secondary electrons are utilized and the wall effect of the chamber is avoided, produces in 1 cc. of atmospheric air at 0° C. and 76 cm. mercury pressure, such a degree of conductivity that one electrostatic unit of charge is measured at saturation current." Let us discuss this definition step by step and see its extent and its limitations.

The only real way of avoiding the wall effect (which means the production of secondary radiation by the beam in traversing the walls

* In the last edition this chapter was revised by Dr. Edith H. Quimby. Some of the material added by Dr. Quimby has been retained in this edition.

[1] There seems to be confusion in the minds of many dermatologists and radiologists relative to the terms *quantity*, *intensity* and *dose*. It should be noted that intensity refers to quantity delivered *per unit time* and should always be so specified. For example, if 100 units of radiation were delivered in ten minutes, the intensity would be 10 units per minute. (This is not a physically accurate definition of intensity, which is the quantity of energy passing through unit area per second. It is, however, the generally accepted one in radiation therapy.) *Dose* is a non-technical term rather loosely used to specify quantity of radiation delivered to a given region.

of an instrument) is to have no walls. Therefore, the standard instrument for measuring ionization current is an open chamber which consists of two parallel plates, between which the x-rays pass. The beam is properly diaphragmed before it enters the chamber, it traverses no solid material. One plate is charged positively and the other negatively, so that the ions formed by the x-rays are attracted to them, thus producing the ionization current (See Chapter XI.)

Utilization of all the secondary electrons means that they must have spent all their energy in producing ions The charged plates must, therefore, be so far apart that the secondary electrons do not reach them before this has happened. Since in a wall-less ionization chamber, the only secondary electrons to be considered are those generated in the air itself, and for ordinary x-rays these have little energy, this distance need be only a few centimeters.

Saturation current means that the difference in potential between the two electrodes must be great enough to make the ions move toward them so fast that none has time to *recombine* with an ion of opposite sign before it reaches an electrode. This is the only method by which it can be assured that all of the ions produced are measured. Evidently if only a few ions are produced, the opportunity for recombination will not be so great as when there are many. Therefore, the greater the amount of ionization, the greater the difference in potential between the electrodes necessary to provide saturation current.

The electrostatic unit of charge has been defined. One electrostatic unit of charge per second is one electrostatic unit of current, which is of the order of one-billionth of an ampere. This is an exceedingly small current, but it can be measured by suitable instruments.

Limitations of Measurement in Terms of the Roentgen—Special ionization chambers need to be constructed to measure radiations of very low voltage or very high voltage and gamma rays. Modification in the definition of the roentgen was necessary to provide for measurement of gamma rays as well as x-rays in terms of the same unit. The new definition of the roentgen follows: "The roentgen shall be the quantity of x- or gamma radiation such that the associated corpuscular emission per 0 001293 grams of air, produces in air ions carrying 1 electrostatic unit of quantity of electricity of either sign"

The standard ionization chamber is a complicated and difficult instrument to use It has been found that certain simpler and more convenient instruments can be calibrated by comparison with a standard, and used for practical purposes Such instruments will be described in a later chapter

When x-rays strike tissue, secondary rays are generated, some of which are so soft that they would not be properly included in an ordinary measuring instrument. Such rays do not exist in the beam by which the portable practical "r-meter" is calibrated against the standard instrument Therefore, when an attempt is made to use the practical instrument to measure such radiation, it is being used under

conditions for which it has not been calibrated For this reason measurements made with r meters lying on the skin are subject to considerable error This matter will be discussed in connection with measurement of dosage

Measurement of Quantity of Radium Radiations — The new definition of the roentgen permits the use of the same unit to measure gamma rays as well as *x* rays Ionization measurements are rapidly replacing older methods of gamma ray measurements The old method of specifying the milligrams of radium or millicuries of radon and the various physical factors (filter distance etc) is practical and is a measurement of a biologic reaction This is inconvenient but does supply an exact specification of the radiation since the output from a given quantity of radioactive material under given conditions is always the same

It should be noted that there are two commonly used methods for specifying the quantity of radium radiation in this manner In one the number of milligrams and the exposure time or the milligram hours (or millicurie-hours) are stated In the other the amount of radon disintegrating during the exposure is given (millicuries destroyed) This method may be used even though radium instead of radon is the source, for there is actually radon in the radium tube The former method is usually used in this country and England, the latter, on the continent of Europe particularly in France Recently however, the second method is more often used to denote quantity of radiation delivered interstitially The two specifications are easily translated one into the other It is known that in the total destruction of 1 mc 133 mc-hr of radiation are delivered Hence 133 mc-hr are equivalent to 1 mc destroyed

The objection is raised to stating *x* rays in terms of one unit and gamma rays in another that it is then impossible to combine them when talking about dosage This may not really be a handicap for as we shall see when we come to biologic effects even when we can measure 1 roentgen of gamma rays we cannot by any means be sure that it would produce the same biologic effect as 1 roentgen of *x* rays

Measurement of Quality — If the measurement of quantity of radiation is fairly well established that of quality is far from it In the first place we have no simple conception of what we mean by quality The quality of an *x* ray beam deals with its penetrability The higher the voltage the greater is the power of an *x* ray beam to penetrate All *x* ray beams are heterogenous because they are made up of *x*-rays of different wave lengths The resultant penetrability or quality of *x* rays is determined by the following methods

1 Standard absorption curves
2 Effective wave length
3 Half-value layer
4 Spectrometric measurements

The first measure of quality was a statement of the spark gap. This measures the *peak* or highest voltage in the cycle, but tells nothing about how much of the energy is delivered at that voltage, or about any of the rest of the cycle. The only way to have a knowledge of the complete cycle is to make a spectrum analysis. A heterogenous beam of x-rays may be broken up by passage through a crystal, and the

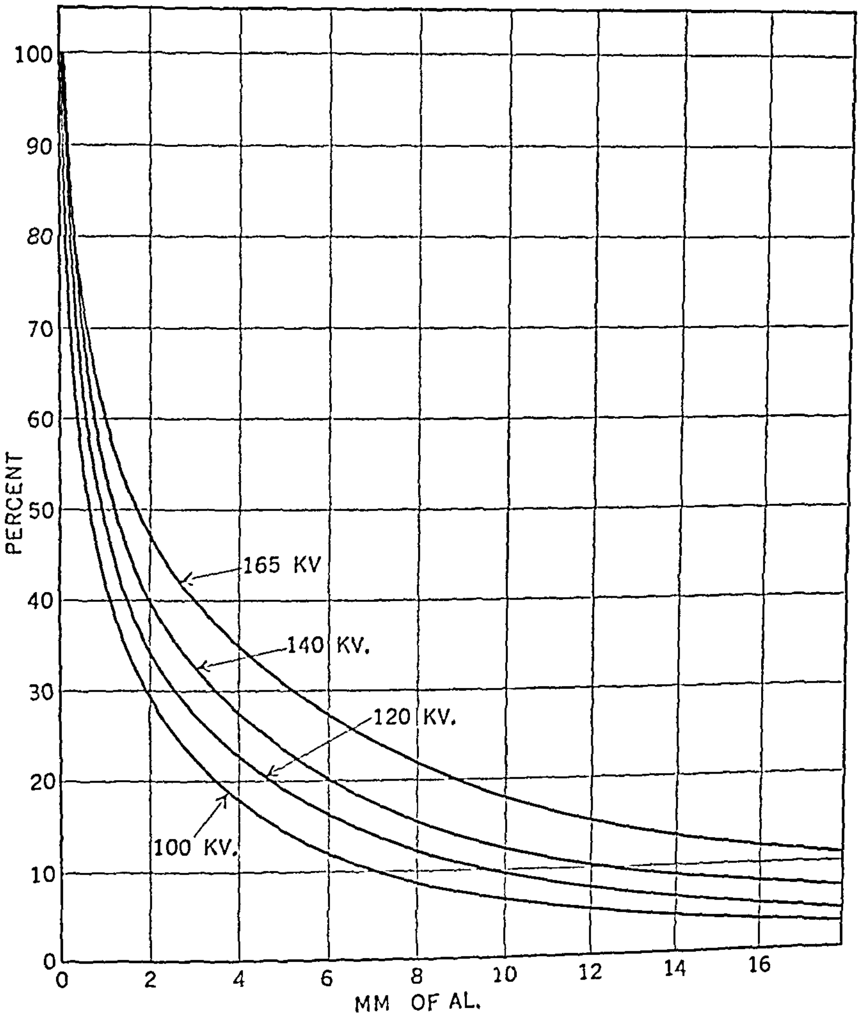


FIG 45.—Absorption curves in aluminum for x-rays generated at different peak voltages, actual percentages of radiation transmitted by different thicknesses (Thoraeus, Acta radiologica, courtesy of P A Norstedt & Son)

intensity of each wave length component determined photographically This is a difficult and tedious procedure.

For practical purposes it is necessary to have something more definite than the spark-gap specification, but nothing so precise as the spectrum curve. Several practical schemes are used, all of them depend in some way on the absorption of the radiation in a metal.

Absorption Coefficient —A given beam of radiation will always have its intensity reduced in exactly the same manner by passing through the same amount of matter If the intensity of the beam as it leaves the tube is taken as 100 per cent and its intensity measured after it has traversed successive layers of some metal say aluminum its gradual decrease can be plotted in a curve which shows the percentage

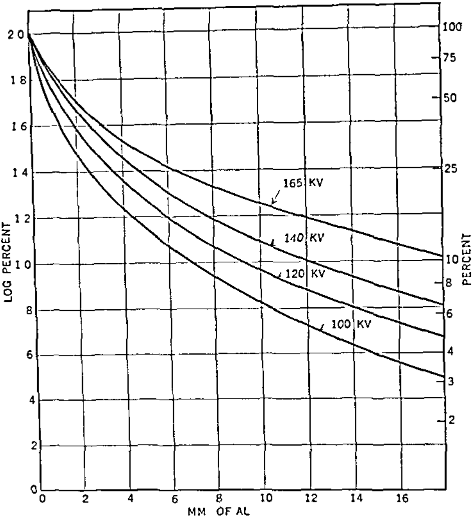


FIG 46 —Absorption curves in aluminum for x rays generated at different peak voltages logarithms of same percentages as in Figure 45 (Thoraeus Acta radiologica courtesy of P A Norstedt & Son)

transmitted by any thickness of metal Figs 45 and 46 show a group of the so called *absorption curves* in aluminum for radiation at different peak voltages In Fig 45 the actual values of the intensities are plotted the curves are very steep and it is difficult to read the values from them In Fig 46 the logarithms of the intensities are used The curves are now almost straight lines the logarithms may be easily read and the actual values found from any logarithm table

7

For convenience a percentage scale has been added at the right of this chart. If the radiation were monochromatic, then 1 mm. of any specific filter would reduce it by a certain per cent, the next millimeter would reduce what was left by the same per cent, and so on. The mathematical expression for this type of absorption is exactly like that for radioactive decay, in which the same per cent of material present always disintegrates in the same length of time.

Effective Wave Length.—Over a given limited range of filtration, a heterogeneous beam may be absorbed in about the same way as a particular monochromatic beam. In this case the quality of the heterogeneous beam is effectively the same as that of the monochromatic; we say the former has the same effective wave length as the latter. The effective wave length of a given beam is found by determining its absorption in a specified filter, usually 0.25 or 0.5 mm. of copper, and then, by referring to curves or tables, finding the wave length of monochromatic radiation which is absorbed in the same way. This was for some time the generally used method of specifying quality. Since it is now falling into disuse, data for its determination will not be included here.

Half-Value Layer.—The method generally used at present is the specification of the half-value layer. This is the thickness of any specified metal, usually copper or aluminum, which reduces the intensity of the incident beam to one-half its value. Mathematically it corresponds to the half-value period for radioactive substances. It is obtained by making an absorption curve for the given beam in the specified material, and reading from the curve the thickness, which reduces the intensity to 50 per cent.

The method of determining the half-value layer for a particular beam of radiation may be illustrated from Figs. 45 and 46. For rays generated by 140 kv. and with no filter, the intensity is reduced to 50 per cent at 1.3 mm. of Al. This, then, is the half-value layer for that quality of radiation. If the beam is filtered by 4 mm. of Al to begin with, the curve shows that the intensity is 27.5 per cent. Half of this is 13.8. The curve indicates this intensity at 9 mm. The half-value layer for this quality of radiation is then 9 mm.—4 mm., or 5 mm. of Al. (The 4 mm. must be subtracted because, being the original filter, it was in place for both readings.)

None of these practical measures of quality is definitive of a certain type of radiation; they all indicate an average effect. It is possible for several quite different beams to have the same quality by any of these criteria. For instance, radiation of fairly high voltage, unfiltered, will contain a portion of fairly soft radiation, which will reduce the average quality so that it may be the same as that of a lower voltage from which the softer rays have been removed by a preliminary filter.

The dermatologist is usually confused when one speaks of absorption curves. In order to clarify this problem Cipollaro and Mutscheller performed experiments with those qualities of *x*-rays, including grenz

rays which are commonly used in dermatologic practice One curve with a 3 mm Al filter was also obtained These curves were superimposed upon a diagrammatic section of the skin in order to visualize easily where different qualities of x rays would have their maximum effect It is seen in the figure that at a depth of 3 mm, practically all

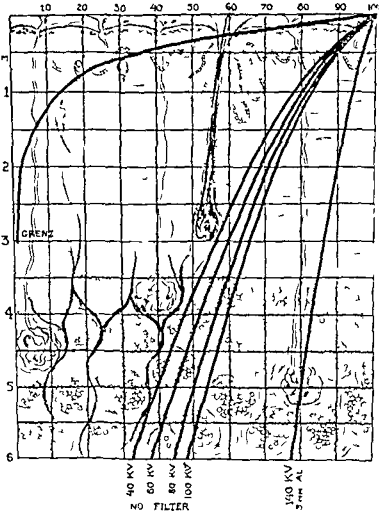


FIG 47 —Absorption curves showing depth doses of various radiations used in dermatologic practice superimposed with correct dimensions over a cross sectional diagram of the skin The measurements were made in air with a Victoreen iontoquantimeter The apparatus used was a mechanical rectifier with a universal type Coolidge tube The peak voltages varied from 40 to 140 the milliamperage from 3 to 5 the skin focal distance was 50 cm and the portal 3 by 3 cm For measurements with 10 kv a Westinghouse air cooled tube grenz ray apparatus was used Special chambers were constructed for the iontoquantimeter (From Cipollaro and Mutscheller)

the grenz rays (10 kv) are absorbed and therefore could have no effect on lesions situated at this level with dosages which are considered safe and harmless at the surface The difference in absorption with radiations of 40 to 100 kv (no filter) at the 3 mm level is only about 10 per cent With 100 kv the absorption is about 34 per

cent and with 40 kv. it is about 44 per cent. With 140 kv. and 3 mm. Al filter the absorption at the 3 mm. level is about 14 per cent. The figure shows graphically the desired quality of radiation to employ for cutaneous lesions of varying thicknesses. The practical measurement for the quality of x-rays generally employed in the treatment of skin diseases is the half-value layer. Spectrometric methods are the most accurate and scientific means of measuring quality of radiation.

Spectroscopy.—In the three previous editions of this book considerable space was devoted to x-ray spectroscopy. In spite of all efforts to simplify this phase of physics the material was still too difficult for the average dermatologist to comprehend fully It was therefore decided to eliminate the chapter on Spectroscopy altogether Besides its complexity, x-ray spectroscopy is not a procedure which can be carried out in the average x-ray laboratory. Its field of usefulness for the average dermatologist is very limited. A few general remarks, however, serve to indicate the use of x-ray spectroscopy.

It has already been indicated that a beam of x-rays contains a wide range of wave lengths. The three previous methods described specify the quality in a general way of all the components of an x-ray beam. The only true description of the distribution of the various wave lengths is to be obtained by spectrum analysis. Such an analysis will reveal in any x-ray beam just what part of the total energy is due to each wave length. Special crystals are used as diffraction gratings and specially constructed spectrometers are used for x-ray spectroscopy. The Seeman spectrograph is a practical instrument especially adapted for radiologic laboratories.

A method which defines the quality somewhat more uniquely is that of adopting a standard set of absorption curves, and fitting the experimental curve to one of them Taylor, at the Bureau of Standards, has published sets of curves for standard voltages, for both pulsating and constant potentials, which may well serve as quality standards [1] These have been discussed, and some of them presented in Chapter IV in connection with the discussion of voltage determination

BIBLIOGRAPHY

BURBY, J J, and BARRY, M W Comparative Measurements of the Quality of Roentgen Rays, Radiology, **12**, 275, 1929

CIPOLLARO, A C, and MUTSCHELLER, A Absorption of Roentgen Rays by the Skin, Arch Dermat and Syph, **41**, 87, 1940

CLARK, G L Applied X-rays, 3d ed, New York, McGraw-Hill Company, 1940

COMPTON, A H, and ALLISON, S K X-rays in Theory and Experiment, New York, D Van Nostrand Company 1935

FAILLA, G Criteria for the Design of a Standard Ionization Chamber, Am Jour Roentgenol and Rad Ther, **21**, 47, 1929

[Fifth International Congress of Radiology] Recommendations of International Committee for Radiological Units, Radiology, **29**, 634, 1937

[1] The Bureau of Standards Bulletin containing these data should be in the hands of every radiologist It may be obtained from the Superintendent of Documents, Washington, D C (Research paper RP666, price 5 cents)

HOLTHUSEN H and GOLLWITZER H Die Qualitätsmessung der Röntgenstrahlen in der Tiefentherapie Strahlentherapie 26 101 1927

MAYNEORD W V and ROBERTS J E The Quality of High Voltage Radiations I Brit Jour Radiol 8 341 1935

QUIMBY EDITH H A Comparison of Practical Methods of Measuring Roentgen Ray Quality for Therapy Am Jour Roentgenol and Rad Ther 21 64 1929

SIEGBAHN Spektroskopie der Roentgenstrahlen 2d ed Berlin Julius Springer 1931

Standards of Measurement and Protection Editorial in Am Jour Roentgenol and Rad Ther 20 553 1928

STENSTROM K W Roentgen Rays Spectroscopy in Glasser O ed Medical Physics Chicago The Year Book Publishers 1944 p 1389

TAYLOR LAURISTON S The Problem of International X ray Standardization Radiology 14 531 1930

THORAEUS ROBERT A Study of the Ionization Method for Measuring the Intensity and Absorption of Roentgen Rays and of Different Filters Used in Therapy Acta radiol supp 15 pp 1-88 1932

CHAPTER X.

PHYSICAL FACTORS AFFECTING QUANTITY AND QUALITY OF RADIATION *

CERTAIN physical factors characterize any radiation exposure. For a beam of x-rays, we must consider the milliamperes, kilovolts, filter, distance from target, time of exposure, and, in the case of quantity of radiation delivered on the skin, the size of the irradiated area. For radium rays there is a corresponding factor for everything except kilovolts—quantity of radium, filter, distance from radium, time, size of irradiated field, and, in addition, the area of the radiating source Changing any of these factors changes the quality of radiation delivered at a given point, and changing some of them also changes the quality They will be considered in detail

Current, or Milliamperes.—Increasing the current is accomplished by increasing the heat of the filament, so that more electrons are released The more the electrons, the more the amount of x-rays produced No change in quality results from this increase in quantity, provided the voltage is maintained constant. With increase in quantity due to raising the milliamperes, the time necessary to deliver a given amount of radiation is decreased in the same ratio

Kilovoltage.—When the potential difference between the filament and the target is increased, all the electrons are driven faster Each one then generates radiation more penetrating than it did before. For any given potential difference the fastest electrons will generate x-rays of a certain maximum frequency or minimum wave length, and these are the most penetrating rays which can be obtained with that voltage There will be few of these extreme rays, but many more with slightly less energy, or slightly longer wave length There will also be rays so soft that they cannot penetrate the wall of the x-ray tube

Filter—In a beam of radium rays there are three types of radiation, the alpha, beta and gamma rays We may depict them, with condensation, by such a diagram as Fig 48. If a sheet of paper be laid over the source, the alpha rays will all be eliminated. The quality of the total beam will then have been markedly changed, but the quality of the beta and gamma portions is little altered The same thing is true of the quantity If now layers of metal filter are added, the softer beta rays, and then the harder, will be removed, thus changing gradually

* In the last edition, this chapter was revised by Dr Edith H Quimby Some of the material added by Dr Quimby has been retained in this edition

both the quality and the quantity of the radiation in the beam. The filter which removes all the beta rays will also remove the softer gamma rays. The removal of rays of any one wave length is not an instantaneous process. The rays are repeatedly reduced in energy by atomic or electronic collisions until they are completely used up.

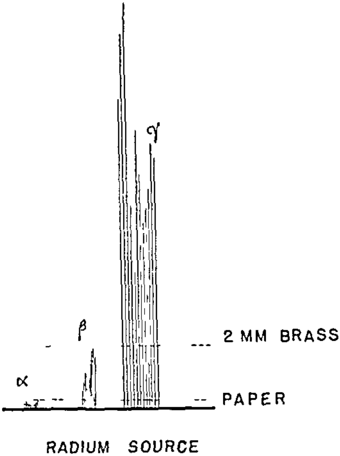


FIG. 48.—Heterogeneous beam of rays from radium source and the effect of filters thereon.

In Fig. 49 are given curves to show the absorption by various filters of the radiation from a thin glass tube containing radon in equilibrium with its products. The logarithms of the intensities are plotted, since the range is so great; however, actual intensities are indicated on the scale rather than logarithms, so that approximate values may be read directly from the curves. Besides various metals, values for pure gum rubber are given, since this material absorbs the radiations in very much the same manner as tissue. For every absorber the radiation is seen to fall off very rapidly at first as the softer components are removed, and then much more slowly. When only gamma rays remain the absorption goes on very slowly, that is, a considerable thickness of absorber is necessary to produce a marked reduction in the intensity of the beam. From the curves it is not

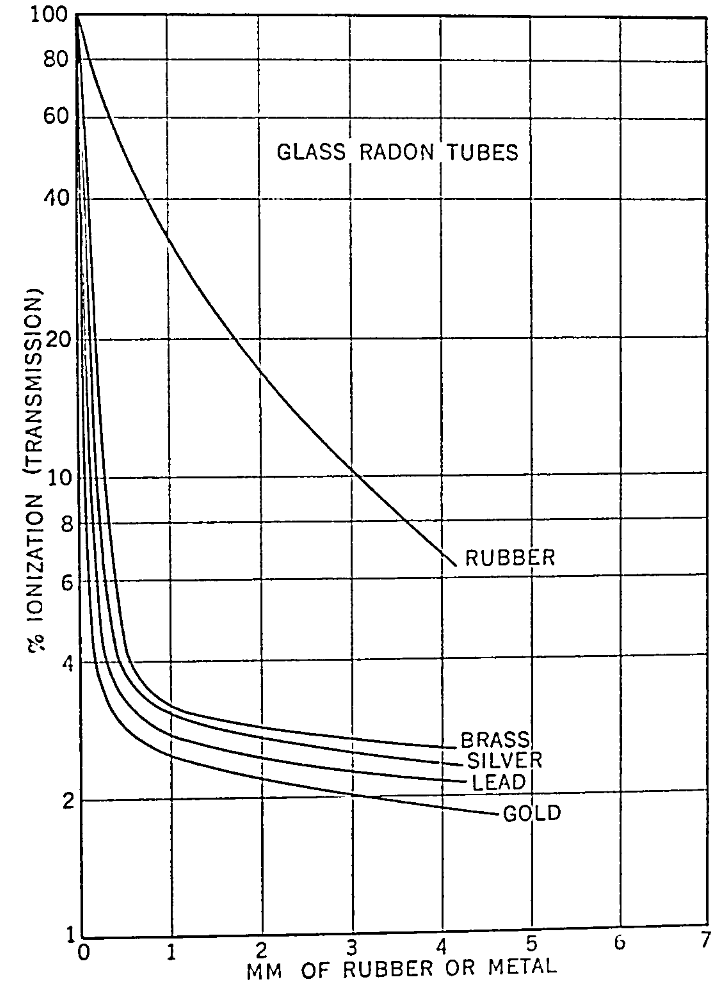


Fig 49 —Absorption curves for radium rays in different substances

Table 11 —Data Concerning Radium Radiations Transmitted by Various Filters (Quimby and Failla, The Science of Radiology courtesy of Charles C Thomas)

Filter	Percentage of total radiation transmitted	Composition of radiation		Percentage absorbed in first cm of tissue
		Beta	Gamma	
Glass tube	100	96 5	3 5	97
0 5 mm brass	4 1	25	75	37
1 0 mm brass	3 0	3	97	11
2 0 mm brass	2 8	0	100	7
0 5 mm silver	3 2	7	93	11
1 0 mm silver	2 8	0	100	7
0 5 mm lead	3 0	6	94	15
1 0 mm lead	2 7	0	100	7
2 0 mm lead	2 5	0	100	6
0 2 mm platinum	3 5	17	83	22
0 5 mm platinum	2 8	0	100	7
1 0 mm platinum	2 5	0	100	6

possible to determine the relative amounts of beta and gamma radiation in the beams This can be done experimentally by deflecting the beta rays by means of a magnet and determining the intensity of the gamma rays alone Table 11 gives data concerning the absolute and relative amounts of radiation transmitted by various filters, and the percentage of the filtered radiation subsequently absorbed in the first centimeter of tissue

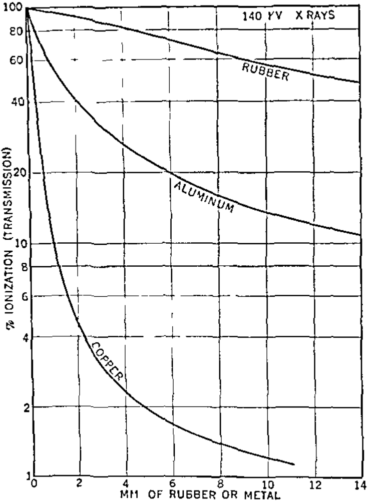


Fig. 30 —Absorption curves for 140 kv x rays in different substances

The question of the best filter for gamma ray therapy is not definitely settled From table 11 it is seen that all beta rays can be removed by about 2 mm of brass, 1 mm of silver or lead (actually 1 1 mm of silver and 0 9 mm of lead) or 0 5 mm of platinum (or gold)

In a beam of x-rays the quality range is not so great as in the radiation from a glass radon tube, but it is still considerable Any filter reduces the energy in the beam traversing it by taking a little energy from every photon Those which had only a small amount at first lose a greater percentage of their energy, so that the *average* energy per photon

will be increased, although actually each will have lost some. The reduction in *quantity* of 140 kv. x-rays on passing through various filters is shown in Fig. 50. A change in quality goes with this reduction in quantity. The x-ray beam becomes harder or more penetrating. From the curve it is seen that increasing the filter for 140 kv x-rays from no metal to 5 mm. of aluminum reduces the intensity of the radiation to 24 per cent of its initial value.

Data of this sort, for various types of tubes and generators, and for a wide range of voltages, are available in the literature. Professional calibration of an x-ray machine should include a determination of the quantity and the quality of the radiation delivered under various specified conditions of voltage and filter.

Secondary Filter.—In passing through a metal filter, x-rays or gamma rays generate therein secondary beta rays and the characteristic radiation of the metal; these secondary rays are mixed with the emergent beam. The secondary radiation is, in general, much less penetrating than the primary beam. For instance, the K radiation of copper is equivalent to about 9 kv. x-rays. Such radiation is readily absorbed by very superficial layers of tissue, and is undesirable in the therapeutic beam. It is therefore necessary to remove these rays by absorbing them in a secondary filter of material which will itself give off no objectionable radiation. Aluminum is a good absorber for the copper rays; its own characteristic radiation is equivalent to only about 2 kv. x-rays and is absorbed in a few centimeters of air.

For radium, the filter materials generally used, platinum and lead, have more powerful characteristic radiations, about 80 and 90 kv. respectively. The secondary beta rays generated by gamma rays are also more penetrating than those due to x-rays. In this case, with large containers used at a distance, it is customary to use brass to absorb the secondary radiation from the lead, and, in turn, celluloid or rubber to absorb that from the brass. For tubes used on or close to the skin, or in body cavities, dependence has to be put ordinarily on rubber alone, and in interstitial irradiation the secondary radiation is allowed to enter the tissues, since in this case it is not damaging the skin and is serving a useful purpose.

Distance.—When the distance between the source of radiation and the area to be treated is increased there is a decrease in the intensity of radiation due to two factors. The first factor is the absorption of x-rays in the matter through which they traverse and the second factor is geometrical. That is the intensity of the radiation falling on a unit area becomes less with increased distance. This is easily demonstrated by a simple diagram such as Fig. 51. The entire beam of rays passes through the small area at the position A. In the position B some distance farther away, the beam has spread out to cover the much larger area. It is evident that the amount passing through 1 sq. cm. at A will be greater than that for 1 sq. cm at B in direct ratio as the area of B is greater than that of A. When the distance

of B is twice that of A, its area is four times as great, so that the intensity per sq cm at B can be only one-fourth as much as at A For any other distances, the areas can be shown to be in the ratio of the squares of the distances Therefore, the intensities must be inversely in the ratio of these squares This is the statement of the *inverse square law* which is a simple geometrical property holding for all sorts of energy emitted uniformly from a point source Evidently, since with change of distance the intensity is reproduced in the ratio of the squares, the time of exposure will have to be increased in the same ratio in order to deliver the same quantity of radiation For example, doubling the distance reduces the intensity of radiation to one-fourth, therefore, four times as long an exposure is necessary to deliver the same quantity of radiation

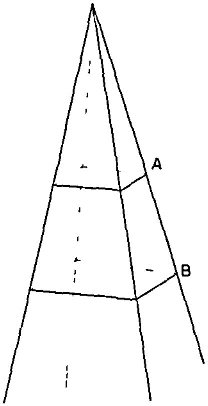


FIG 51 —Diagram illustrating reduction in intensity of radiation with increase in distance (Inverse square law)

If the source of rays is not a point, the variation in intensity will be less, but it will always exist (unless in some manner the rays are made parallel and kept from spreading) In most x-ray tubes the area of the target may be considered as effectively a point source If the filter is close to the tube it will usually be found that the law is followed If however, the filter is close to the skin, or cones are used which may act as secondary radiators, considerable variation from the law may be found to exist For any given installation, the variation

MacKee, George M., Mutscheller, Arthur, and Cipollaro, Anthony C.: Time Factor in Irradiation, Arch. Dermat and Syph., 47, 490, 1943

——— The Area Factor in Roentgen Irradiation, Arch. Dermat and Syph, 47, 657, 1943

Mayneord, W. V., and Roberts, J. E: Measurements of High Voltage X-Rays, Brit Jour. Radiol., 6, 321, 1933.

Quimby, Edith H., and Failla, G.: Radium Dosimetry, in Glasser, O., ed: *Science of Radiology*, Springfield, Ill., Charles C Thomas, 1933.

Quimby, Edith H, Marinelli, L D., and Farrow, J.: A Study of Back Scatter, Am. Jour. Roentgenol and Rad. Ther., (In press).

Terrill, H. M., and Ulrey, C. T.: *X-ray Technology*, New York, D. Van Nostrand Company, 1930

CHAPTER XI

METHODS OF MEASURING QUANTITY OF RADIATION [1]

A QUANTITY of energy can be measured only by the effects it produces. Any one of the phenomena resulting from the action of x-rays might be used as a basis for measurement, and many have been so adapted. The effects of radiation may be classified as fluorescent, photographic, thermal, chemical, biological and electrical. The criteria for a practical system of measurement are that the procedure should not be too complicated or require too great technical skill, the method should be sensitive enough to permit the accurate determination of quantities considerably less than those ordinarily used in therapy, apparatus should be simple and rugged, and should not contain inherent factors of error. It should be possible to duplicate results readily. The method should be objective rather than subjective, that is the judgment of the observer should not play an important part in the result. There should be no time factor, that is, the rate of delivery of the radiation should make no difference in the result obtained.

Unfortunately, no method at present available combines all these desiderata. Some, however, are much better than others. It is the purpose of this chapter to discuss briefly various useful methods, and somewhat in detail the ionization measurements which are at present the most satisfactory and most generally used.

Two of the groups of phenomena listed above may be discarded for our purpose. Fluorescent effects are not sufficiently sensitive to variations in intensity to be of any practical value. Thermal effects (the production of heat as a result of the absorption of radiation) have been used to measure the total energy in a beam. In the hands of skilled physicists, the method had yielded valuable data, but the technical training and delicate measurements involved make it of little practical value outside a research laboratory.

PHOTOGRAPHIC METHODS [3]

Photographic methods depend on the fact that x-rays darken photographic film, and that within certain limits the amount of darkening is proportional to the amount of radiation used. Their advantages

[1] In the last edition this chapter was revised by Dr. Edith H. Quimby. Some of the material added by Dr. Quimby has been retained in this edition.

[2] Of course photographic effects are chemical, but they are usually considered separately.

[3] Photographic, pastille and other chemical methods of estimating x-ray quantity and intensity are only briefly mentioned in this edition. The first two are practically obsolete in this country. Those who are especially interested in these methods will find a discussion of the subject with literary references in the first and second editions of this book. Other chemical methods are of little practical importance at the present time.

are the availability of the materials, the simplicity of their application, and the fact that no special skill is required in their use. The disadvantages of the method are inherent in these same facts. Carelessness in dark room technic may completely vitiate measurements For results to be of any value, a complete set of standard films must be prepared with every experimental set. As ordinarily used, with visual determination of relative densities, the judgment of the operator plays an important part. With ordinary beams used in therapy, complete blackening is obtained with quantities of radiation less than 1 per cent of those required to produce a visible effect on the human skin. Moreover, the photographic effect is extremely dependent on the quality of the radiation employed, so that comparisons with different qualities are completely impossible. However, even in view of all these drawbacks, the method is useful within limits. One of its advantages is the absence of a time factor within very wide limits, which makes it useful for testing protection in *x*-ray departments, by measuring the amount of radiation reaching a given spot in a period of days or weeks.

CHEMICAL METHODS.

Pastilles—Under the action of radiation, various substances undergo temporary or permanent color changes The first attempts at accurate measurement of radiation doses were based on such phenomena, the substance most commonly used being barium platinocyanide. This, when fresh, fluoresces with a brilliant green color. Under exposure to *x*-rays it changes to an orange and then to a brown color, which becomes gradually darker the greater the amount of radiation. The various pastille radiometers were provided with standard color scales The test pastille was exposed during the irradiation of the patient, and compared, under proper illumination, with the standard Treatment could be interrupted at any time to ascertain how much had been delivered, and the pastille returned to its place.

The use of these radiometers marked a great step forward in radiation therapy. In the days of gas tubes and other unsteady apparatus, it was necessary to measure the dose for every treatment, if trouble was to be avoided and the desired results obtained. With present tubes and apparatus the output of a given machine will not vary more than a few per cent as long as no actual breakdown occurs, and occasional calibrations are all that are necessary, although many radiologists prefer to use dosimeters for every case.

Pastille measurements were always uncertain, because of spontaneous changes in both the pastilles and the color index with age The speed with which a reading was made was of great importance, since the color change induced by radiation was very temporary in nature. They are obsolete in this country at the present time.[1]

[1] See footnote under photographic measurements

Chemical Changes Produced by Radiation —Numerous chemical changes are brought about by the action of radiation and theoretically, any of these may be used to measure the energy consumed As a matter of fact very few of them are of any practical value

BIOLOGIC METHODS

Practically all biologic material is affected to some extent by radiation and many such reactions have been suggested as standard for the measurement of radiation doses It is argued that since in therapy we are interested in a biologic effect, a biologic standard should be used Against this may be set the variability of living material as compared to lifeless, necessitating many experiments to determine a single value There is also the fact that no biologic reaction is immediate, but that the lapse of days or weeks is necessary before the result can be determined whereas with other methods it can be known in a few minutes

However, two types of biologic measurements are deserving of consideration the first because of the high degree of precision to which it has been brought *in skilled hands*, the second because of the universality of its application They are the effect of radiations on the eggs of the fruit fly and on the human skin

Killing the Eggs of the Fruit Fly (Drosophila) —Young flies from a pure culture of wild *drosophila* are transferred from the bottles in which they are bred, to clean empty bottles, containing strips of black filter paper moistened with a special food of yeast and banana juice These bottles are put into an incubator at 26° C and left undisturbed for two hours at the end of which time many eggs will have been laid on the black papers These are removed and spread closely on fresh pieces of damp black paper by means of a small camel's hair brush They are then placed in a moist chamber Exactly one hour after the end of the laying period, they are irradiated all of the slips with eggs being started simultaneously, and one after another withdrawn when it has received the desired dose During the irradiation the slips are supported on gauze held in a light wooden frame sufficiently large that the wood is outside the direct beam The gauze is kept damp with banana juice The maximum exposure should not be greater than twenty-five minutes, and the radiation intensity not less than 5 r per minute After irradiation, the eggs are kept at room temperature in a moist chamber Under these conditions they hatch in thirty-six to forty eight hours Those which have hatched can be easily distinguished by the wrinkled, parchment like appearance of the empty shell in contrast to the plump dead eggs

From the data on many thousands of flies irradiated in this manner it has been possible to draw a curve relating the percentage surviving with the amount of radiation used This is given in Fig 52 It has been obtained by workers in several different laboratories and may be

considered reliable, *provided two-hour eggs are used, and the technic described is followed exactly.*

In order to use the eggs to measure the radiation from a given beam, the percentage survival after a given irradiation is determined. For instance, suppose that 60 per cent of the eggs irradiated survived, it is seen from the curve that this indicates a dose of 220 r. If this was delivered in ten minutes it means an output of 22 roentgens per minute. Of course such a single measurement should never be used. Different batches of eggs should be exposed for different times, and the average of all the determinations taken. Extremes of killing, that is, 10 per cent survival or 90 per cent survival, are not as reliable as intermediate ones, for the presence of a few unusually sensitive or unusually resistant eggs may unbalance these end points.

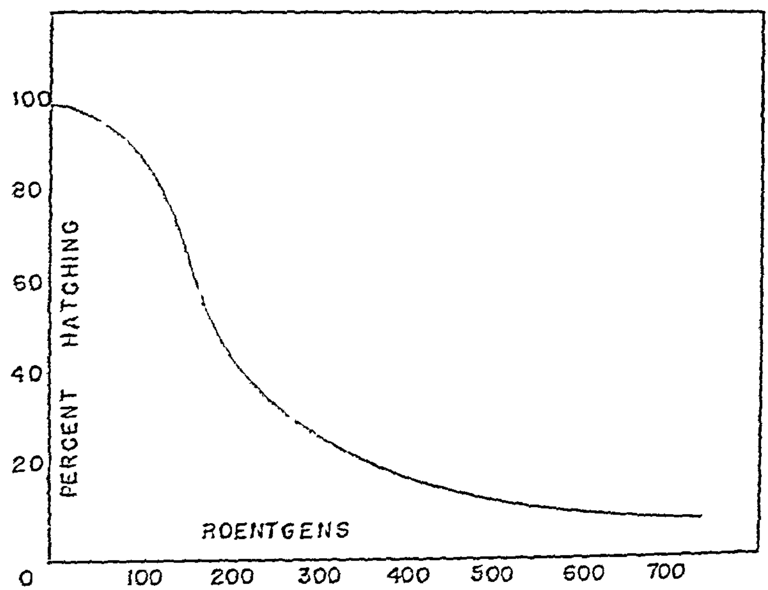


FIG. 52.—Survival curve for eggs of *Drosophila Melanogaster* irradiated with x-rays

An advantage often claimed for *drosophila* eggs is that the result is independent of the quality of radiation employed. As a matter of fact, at present there is no means of knowing whether this is true. What is true is that, within a wide range of qualities, the quantity of radiation as determined by the eggs is the same as that determined by the ionization chamber, or that, conversely, equal amounts of radiation, as measured by the standard ionization chamber, produce equal effects in *drosophila* eggs. This simply means that neither type of measurement is necessarily independent of quality, but that if there is a quality effect, it is the same for the eggs and the ionization chamber.

Effect on Human Skin.—Since a definite limitation to radiation therapy is the effect produced on normal skin, it is natural that this reaction should be taken as a standard, and as a practical one it is very useful; however it admits of little precision.

In the first place, the definition of the *skin erythema dose* differs considerably among various workers. Some use a "full erythema dose" — the amount of radiation which will produce a sharp reddening. Others use a "threshold erythema dose," which produces a very faint reddening. Still others use a "threshold pigmentation dose," which may never produce a reddening, but after two weeks or more results in a faint bronzing. All of these have drawbacks. In the first place, there is considerable variation in individual susceptibility to radiation, so that it is necessary to test a number of people before a dose can be determined. Different parts of the body differ in sensitivity, so that one region must be selected and always used. The size of the area irradiated is exceedingly important, for the back scatter in a large field produces a marked increase in the effect from a given amount of radiation. Small fields less than or about 5 square centimeters should be used. The degree of reaction is difficult to determine with different normal skin backgrounds (unless it is pushed to the point of dermatitis). Texture of skin, presence or absence of hair, natural pigmentation or sunburn must be taken into consideration, as must the illumination under which observations are made. Various tintometers have been devised to facilitate reading erythemas and in the hands of some investigators have proved very useful. However, the personal factor is almost as strong with these instruments as without them.

It is to be admitted that the erythema dose is an inaccurate method of measuring x-ray dosage. Yet dosage in dermatologic roentgenotherapy is based upon biologic reaction in the skin produced by x rays. Fractions or multiples of a biologic dose are employed in treating skin diseases. One of the reasons why there is so much discussion regarding the erythema dose is due to the fact that dermatologists and radiologists observe different biologic reactions. The radiologist seldom observes sharp redness one week after exposing an area of skin 2 x 2 cm. He observes a brownish discoloration with some edema. This is due to the fact that the voltages he employs are higher and the filtration is greater than that employed by the dermatologist. The redness observed by the dermatologist is sharp and distinct because he employs low voltage (60 to 100 kv.) and no filter and uses an open Coolidge tube with mechanical or tube rectification. The redness becomes less distinct as the beam of x rays becomes harder.

In determining the erythema dose a number of young white subjects are selected and an area of skin either on the inner surface of the thigh or the flexor surface of the forearm is selected as the test site. The use of irritants, exposure to the sun, trauma and other factors which might provoke redness or an inflammation are to be avoided. Three, five, seven, ten and fourteen days after irradiation the test areas are observed in daylight. The novice will have difficulty at first in distinguishing redness from brown discoloration or tanning. For the unfiltered softer radiations (50 to 100 kv.) a measured dose of 200, 250, 300, 350 and 400 r is applied to each test area on the *same*

part of the body. The test areas are separated by an area of normal skin for purposes of color comparison. A lead mask with appropriate openings is used for this purpose. For filtered (0.5, 1 and 3 mm. Al) and harder radiations (137 kv.) 270 to 720 r are applied to each test area. The measurements we made were in air and a Victoreen r meter which was specially calibrated for low voltages was employed. The intensity of radiation for unfiltered *x*-rays was 150 r per minute, for 0.5 mm. Al was 120 r per minute; for 1 mm. Al was 112.5 r per minute, and for 3 mm. Al it was 68.75 r per minute. Of course there were variations of redness in each group and an average was taken for each group. We noted that the erythema varied with the quality of the radiation, the intensity and the irradiated area. The physical factors were more important than individual differences in reaction of persons of different age, sex or complexion. We thus concluded that 300 r measured in air with a Victoreen r meter specially calibrated for use with low voltages will produce an erythema with 100 kv. and no filter. For voltages lower than 100 kv. the differences were so slight that we did not think it necessary to record them. With 50 kv., no filter. a thin walled open Coolidge and a valve tube rectifier, erythema was repeatedly observed with 250 r. With 137 kv. and 0.5 mm. Al, 400 r; 1 mm. Al, 450 r; and 3 mm. Al, 550 r were required to produce erythema. The table summarizes the relation between roentgen and the erythema dose for roentgen ray qualities ordinarily used in dermatology.

TABLE 12 —RELATION BETWEEN ROENTGENS AND ERYTHEMA DOSES FOR ROENTGEN RAY QUALITIES ORDINARILY USED IN DERMATOLOGY.
(From MacKee and Cipollaro)

Kilovolts.	Filter, millimeters of aluminum.	Number roentgens for erythema.	Intensity, roentgens per minute.	Half-value layer in millimeters of aluminum.	Effective wave length
10 (Grenz)	0	200 to 300	150	0 02	1 75
60	0	300	100	0 8	0 27
80	0	300	100	1 0	0 264
90	0	300	100	1 1	0 260
100	0	300	100	1 3	0 253
115	0	300	100	1 9	0 240
137	0 5	400	120	2 7	0 228
137	1 0	450	112 5	3 0	0 224
137	3 0	550	68 75	4 2	0 213

There is one more qualification for the conception of the erythema dose. For low voltage unfiltered *x*-rays the number of roentgens required to produce erythema should also be sufficient to produce epilation of scalp hair in children. We have found that 300 r is the epilating dose. The measurements were made under the conditions above specified and this dose was used in the epilation of thousands of scalps at the Skin and Cancer Unit. It is interesting to note that the epilating dose does not vary with either the quality of radiation (provided it is sufficiently penetrating to affect the hair papillæ) or

with the intensity Holthusen and Braun were the first to call attention to this and they give their epilating dose as 350 r

Herrmann and Pick in a recent article point out that different areas of the skin vary in sensitiveness to low voltage x rays They found that the axilla and groin are the most sensitive and the palm and sole are the least sensitive They found no appreciable difference on the basis of sex or complexion but that elderly debilitated people were less sensitive than young robust individuals Desjardins believes that this difference in sensitiveness could be explained on the basis of circulation, while Belisario s explanation is based on differences in thickness of the skin Perhaps both ideas play a role in addition to some other unknown factors

The erythema dose is of no value in determining the output from a given source of radiation, it is subject to too great variations, and requires too long a time to complete a series of tests It is a convenient practical method of describing doses delivered in tissues and is valuable as a guide in the treatment of skin diseases

ELECTRICAL OR IONIZATION METHODS

The modern accepted method of measuring the output of an x ray machine is by the utilization of an ionization instrument In any ionization measuring instrument there are two parts, the one which collects the ions, and the one which measures the resulting current In some simple electroscopes the two are combined, but in general the parts are separate, the *ionization chamber*, for the collection of the charged particles being connected electrically with the *measuring instrument*

Standard Ionization Chamber —As was seen in the discussion of units for x ray measurement, it is necessary, for precise standardization, to have an ionization chamber built according to very definite specifications A diagram of such a "standard ionization chamber" is given in Fig 53 It is not a simple device The ionization current is produced between the charged electrode E, and the grounded one, F which is connected to the measuring instrument At either end of F are two grounded plates, GG, to prevent the leakage onto F of extraneous charges which would make the ionization current seem too high These electrodes are enclosed in a heavy lead box, of the dimensions indicated This shielding is necessary in order to be sure that no x-rays enter the chamber except the desired beam The neck carries a series of diaphragms in order that the beam may be precisely limited and its area known From the cross-section of the beam and the length of the electrodes may be calculated the actual volume from which the ions are withdrawn in the measured current, and hence the electrostatic units produced per cubic centimeter Since the x rays do not strike the electrodes nor any part of the chamber inside the diaphragms there are no secondary rays produced except those from

the air itself, which are completely absorbed before they reach the plates. The chamber can, therefore, be made of metal throughout It is large, heavy, and awkward to move about, and must be adjusted with extreme care. It is the standard by which all other chambers must be calibrated, but is itself seldom used outside the physics laboratory.

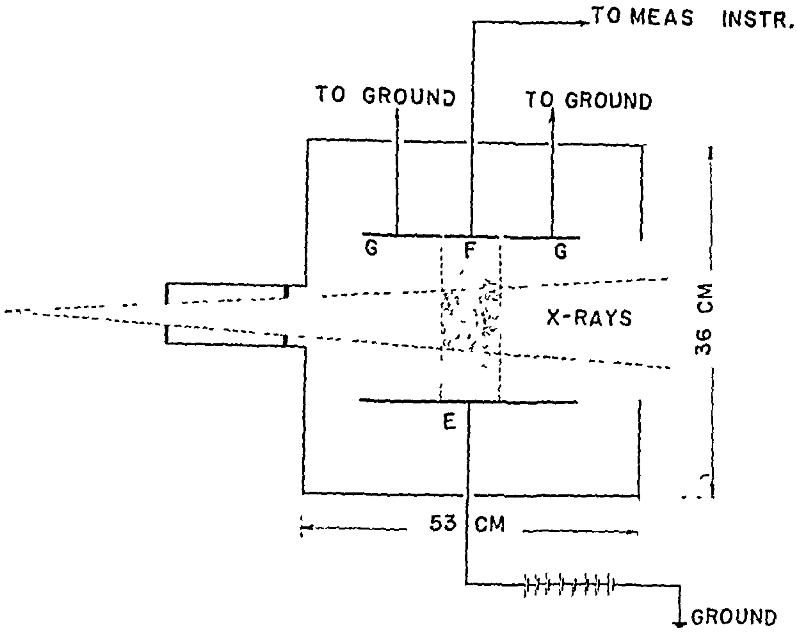


FIG 53 —Standard ionization chamber

Small "Air Wall" Chambers; "Thimble" Chambers.—The chambers usually used for the physical measurement of x-rays are of the thimble type. The outer shell of such chambers is constructed of a conducting material which is grounded and a central electrode connected to a suitable current measuring device. This is charged to a sufficiently high potential to insure saturation between it and the surrounding chamber wall. The wall is made of bakelite, graphite, horn, celluloid or other suitable material. When the chamber is placed in the beam of x-rays, the air within the chamber is ionized, causing a flow of electricity which is recorded on a measuring device

The ionization of air in a thimble chamber is not the same as that of an open chamber The thimble chamber has to be calibrated against the open chamber for voltages for which the thimble is to be used. The thimble chamber will indicate true roentgens only if it is properly calibrated A Victoreen r meter bought at random cannot give true readings for all voltages A properly calibrated thimble type roentgenometer is invaluable in every day therapy. The doses need not be measured with each treatment, but occasionally calibrations of x-ray output in air assures safety and uniformity of dosage.

Condenser Chambers.—Chambers of the small air-wall type are sometimes built in the form of small condensers, which can be completely detached from the measuring instrument. They are so well insulated that when a certain potential difference is developed between the electrodes by charging one of them, they can be carried about and handled without losing this. However, if ions are formed inside by the action of radiation, these will be attracted to the appropriate electrodes, partly counteracting the charge and leaving a smaller potential difference. Such a chamber is attached to a measuring instrument, charged until it registers a certain reading, detached, exposed to radiation, and at any reasonable subsequent time returned to the instrument, whose reading then indicates the total amount of radiation which has fallen upon the chamber.

Such chambers have several advantages. They can be used in many places where a chamber with a connecting cable would be impracticable. If the insulation is sufficiently good, the exposure may last for several days or weeks, making them suitable for testing protection. They may be sent to considerable distances by mail, exposed, and returned for reading. Their drawback is the slowness and tediousness of making many measurements by this method. The roentgenometer used extensively in this country and which is the one which the authors employ, is the Victoreen condenser r meter (Glasser-Seitz type).

Extrapolation Chambers.—An important type of chamber recently developed is the so-called extrapolation chamber, which is a modification of the parallel plate chamber. Its purpose is the accurate measurement of the radiation delivered at the surface or in the interior of a volume of organic matter. This is essentially a laboratory instrument and will not be described here.

BIBLIOGRAPHY

BELISARIO, J. C.: Threshold Erythema Dose of Roentgen Rays. II. An Experimental Investigation of Various Aspects of Erythema Reaction and a New Clinical Criterion for the Standard Threshold Erythema Reaction. Arch. Dermat. and Syph., 45: 641, 1942.

CLARK, G. L.: Applied X Rays. 2d ed. New York, McGraw-Hill Book Company, 1932.

DESJARDINS, A. U.: Action of X Rays and Radium on Pathological Tissue. in G. M. MacKee, X Rays and Radium in the Treatment of Diseases of the Skin. Philadelphia, Lea & Febiger, 1938. p. 269.

FAILLA, G.: The Question of a Biological Unit of Radiation. Acta Radiologica, 6: 413, 1926.

———— The Measurement of X-ray Dosage by Physical Means. Radiology, 13: 293, 1929.

———— Criteria for the Design of a Standard Ionization Chamber. Am. Jour. Roentgenol. and Rad. Ther., 21: 47, 1929.

———— A New Instrument for Measuring X Radiation. Radiology, 15: 437, 1930.

———— The Measurement of Tissue Dose in Terms of the Same Unit for All Ionizing Radiations. Radiology, 29: 202, 1937.

FRICKE, H., and GLASSER, O.: Eine theoretische und experimentelle Untersuchung der kleinen Ionisationkammer. Fortschritte a. d. Geb. d. Roentgenstrahlen, 33: 239, 1925.

GLASSER, O., QUIMBY, E., TAYLOR, L., and WEATHERWAX, J.: Physical Foundations of Radiology. New York, P. B. Hoeber, 1944.

HERRMANN, J. B., and PACK, G. T.: Variations in Sensitiveness of Different Skin Areas to the Erythema Dose of Roentgen Radiation, Am. Jour. Roentgenol. and Rad. Ther., 51, 504, 1944

HOLTHUSEN, H., and BRAUN, R.: Grundlagen und Praxis der Röntgenstrahlen-dosierung, Leipsig, Georg Thieme, 1933

HOLTHUSEN, H.: Der derzeitigen Stand der physikalischen Messmethoden, Strahlentherapie, 22, 1, 1926

HOLTHUSEN, H., und BRAUN, R.: Praktische Erfahrung mit der Dosierung in Roentgeneinheiten und Nomenklaturfragen, Roentgenpraxis, 2, 337, 1930, 3, 193, 1931

HUDSON, J. CRAMER: Roentgen-Ray Dosimetry, in Glasser, O., ed.: Science of Radiology, Springfield, Ill., Charles C Thomas, 1933

KROENIG, B., and FRIEDRICH, W.: The Principles of Physics and Biology of Radiation Therapy, English Translation by Henry Schmitz, New York, Rebman Company, 1922.

MACKEE, GEORGE M., and CIPOLLARO, ANTHONY C.: Roentgen Dosage in Dermatology Expressed in International Roentgens, Arch. Dermat. and Syph., 41, 1, 1940

MAYNEORD, W. V., and ROBERTS, J. E.: The Ionisation Produced in Air by *X* Rays and Gamma Rays, Brit. Jour. Radiol., 7, 158, 1934

PACKARD, CHARLES: The Quantitative Biological Effects of *X*-Rays of Different Wave-Lengths, Jour. Cancer Research, 11, 1, 1927.

SIEVERT, ROLF M.: Eine Methode zur Messung von Rontgen-, Radium- und Ultrastrahlung nebst einige Untersuchungen über die Anwendbarkeit derselben in der Physik und der Medizin, Acta Radiologica, Supplement 14, pp. 1–179, 1932

Symposium on] Relative Effects Produced by 200 Kv. Roentgen rays, 700 Kv. Roentgen rays, and Gamma Rays, Am. Jour. Roentgenol. and Rad. Ther., 29, 293, 1933

I. FAILLA, G., *et al.*: The Distribution of Radiation in a Water Phantom, p. 293

II. WOODWARD, H. Q., *et al.*: Comparison Based on Effects on Iodides, Eder's Solution, and Photographic Film, p. 308

III. HENSHAW, P. S., *et al.*: Comparison Based on Effects on *Drosophila* Eggs and on Wheat Seedlings, p. 326

V. DUFFY, J. J., *et al.*: Comparison Based on Production of Erythema in Human Skin, p. 343.

VII. FAILLA, G.: Correlation of Experimental Results, p. 352.

CHAPTER XII

TISSUE DOSAGE [*]

The purpose of radiation therapy is to produce some change in tissue activity, by the action of the rays on the cells. This action must be brought about by the absorption of some of the energy of the beam of radiation in the cells affected. The present concepts of the mechanism of this absorption and the resultant tissue changes will be discussed in the chapter on Biological Effects of Radiation (Chap. XIX). It may, however, be assumed that the effect produced is proportional to the amount of radiation which actually reaches the tissue in question. From this point of view it is evident that the type of measurement of radiation discussed in Chapter XI is not sufficient. Therein were given particulars regarding the determination of the quantity of radiation in a beam in air, which describes the effectiveness of the source, and also *information regarding the amount of radiation delivered to the surface* of the body under definite conditions. However, it is obviously necessary to have some means of determining and stating the amount of radiation delivered within the tissues.

Methods of Irradiation. — Two general methods are used for the administration of radiation, known as the *external* and the *interstitial*. The first comprises all cases in which the source of radiation is outside the body. Such are practically all x-ray treatments,[1] and application of radium by means of "packs," plaques, or moulages. In the second, the *source of radiation, usually radium or radon, is buried directly in the* tissue to be affected, or inserted into the body cavities.

The two obvious differences between these methods are: (1) In external irradiation only a small part of the available energy actually reaches the tissues. Radiation is emitted in all directions, and only a few per cent of the total form the useful beam. In interstitial irradiation, all of the energy emitted from the source reaches the tissue.

2. In external irradiation, even the useful beam must, in general, first pass through skin and other normal tissues before reaching the diseased cells. The *amount which may* be used is limited by skin tolerance, and this amount is further decreased by absorption in normal tissues overlying the diseased region. In interstitial irradiation the maximum dose may be delivered directly into the diseased structures. It is evident that, if interstitial irradiation could be administered easily, uniformly, and accurately, it would be much the more effective, and in fact, usually the method of choice. However,

[*] In the last edition this chapter was revised by Dr. Edith H. Quimby. Some of the material added by Dr. Quimby has been retained in this edition.

[1] The recently developed x ray tubes for intercavitary use are not *strictly external*, but even here the concepts of external irradiation apply.

it is often impracticable, or otherwise undesirable, and in such cases reliance must be placed on the external method.

Tissue doses of radiation delivered by each method will be considered in detail.

EXTERNAL IRRADIATION.

Although, in general, dosage problems in dermatology do not involve tissue depths of more than a few centimeters, it is considered advisable to present a fairly comprehensive discussion of this subject.

Unit of Measurement.—The question of a satisfactory unit for the measurement of tissue dose has not been settled at the present time. Various physical, chemical, and biological standards have been proposed, but none of them is really satisfactory. The roentgen, discussed in Chapter IX, was established for the measurement of *x*-rays in air. Some revision of the definition will be necessary before it can satisfactorily be applied to gamma rays in air, and even more before it can be safely used as a unit of quantity of radiation within a scattering medium. The unit is essentially a measurement of ionization of air, and such a physical phenomenon will not necessarily indicate the degree of biological reaction to be expected. Due to scattering and the production of secondary rays (*q.v.*) in the tissues, the radiation at a depth is different qualitatively from that on the skin It is a moot question whether doses measured by a physical standard will produce the same biological effect for different qualities of radiation. At the present time the most acceptable unit is a biologic one. When tissue reactions are better understood, it may be practicable to specify dosage on an energy basis, in terms of the number of ions produced per cubic centimeter, or by some other physical statement.[1]

Skin Erythema Dose.—The selection of the proper biologic unit is not easy. Various experimenters have used such indicators as *drosophila* or *ascaris* eggs, seeds, plant shoots, and tumor cells *in vitro,* to compare the reactions of external irradiation by radium and *x*-rays. None of these is satisfactory as a standard from a practical standpoint. Radiologists in general use as a unit the *skin erythema dose, i. e.*, the amount of radiation which will redden the normal skin This is open to the objection that such a dose varies among individuals and among

[1] The new definition of the roentgen, adopted by the Fifth International Congress of Radiology, opens the way to specifying tissue doses in terms of roentgens It is now reasonable to state that a "tissue roentgen" shall be that quantity of *x*- or gamma-radiation whose corpuscular radiation liberates 324 by 10^{10} ions (1 e s u) per gram of air *at the point where the radiation is utilized, and under the conditions under which it is administered.* It now becomes a question of developing instruments which will measure this ionization correctly. The extrapolation chamber is satisfactory for this purpose, and data obtained with it can be expressed in terms of tissue roentgens Thus the back-scatter tables can be used to find the skin doses of *x*-rays in terms of tissue roentgens For data in the present chapter, if the skin doses are expressed in this manner, and percentages then taken according to the curves and tables here given, the results will give the tissue doses reasonably well in terms of tissue roentgens. Until the definition of the actual roentgen is extended to cover such measurements, it is wiser to speak of tissue doses thus specified as in terms of "tissue roentgens" rather than actual roentgens, even though the number of ions is the same in both cases.

observers, some desiring a sharper reddening than others These difficulties may be overcome by using the so-called *"threshold pigmentation dose,'* or *'threshold skin dose"* This is the amount of radiation which, in 80 per cent of all cases, produces a faint bronzing of the skin in two to four weeks after treatment (for gamma rays this time of observation should be extended to six weeks), and in the other 20 per cent produces no visible effect With this unit, the error in determining the dose is less than 10 per cent, and varies very little from one observer to another It is not entirely satisfactory from several points of view, but it appears to be the best available at present

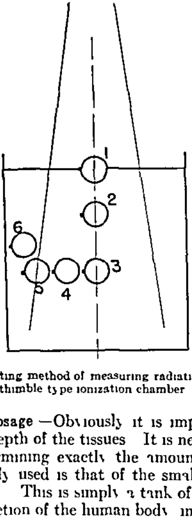


FIG 54 —Diagram illustrating method of measuring radiation in phantom with small thimble type ionization chamber

Determination of Dosage —Obviously it is impossible to observe a skin reaction in the depth of the tissues It is necessary to have some other means of determining exactly the amount of radiation The method most generally used is that of the small ionization chamber and 'water phantom This is simply a tank of water of dimensions comparable with a section of the human body in which the ionization chamber can be immersed It has been found that water scatters and absorbs radiation in practically the same manner as human tissue hence data obtained in this manner are applicable to radiation therapy In fact depth doses measured in a cadaver agreed very closely with those measured in the water phantom

The method of obtaining such data may be outlined as follows In Fig 54, a beam of radiation is shown falling on a tank of water The

ionization chamber in position 1 is half submerged, at the surface. The reading obtained in this position may be taken to correspond to the radiation falling on the skin. It will be greater than the reading obtained with the chamber in the same position and the tank empty, because of the radiation scattered back from the water below. Measurements made with the chamber in positions such as 2 and 3 will give the amount of radiation arriving at various depths along the center of the

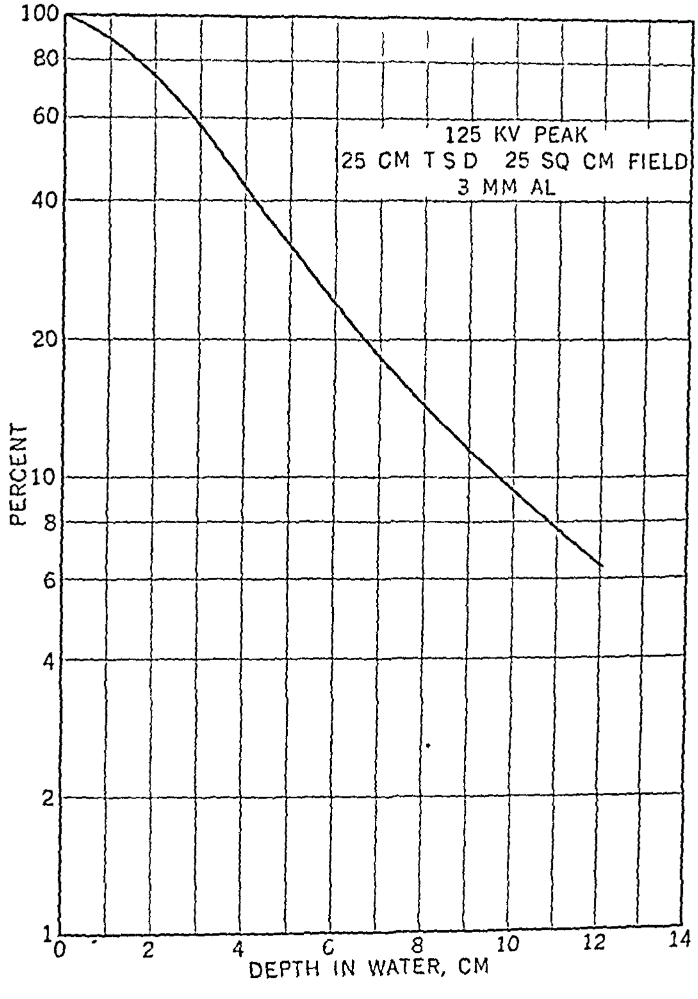


FIG 55.—Curve showing percentage depth dose in water for x-rays generated at 125 kv peak, filtered by 3 mm. Al, 25 cm. T-S distance, 25 sq cm. field.

beam, and in positions such as 4, 5, and 6, values off the axis, and even completely outside the geometrical beam, may be obtained. The reading at the center on the surface is taken as 100 per cent, and all others calculated in terms of this. Useful methods of plotting such data are shown in Figs. 55 and 56. Fig. 55 is the so-called depth dose curve for x-rays generated at 125 kv. peak, filtered by 3 mm. Al, used at a 25 cm. target-skin distance, and falling on a field of 25 sq. cm. From it the amount of radiation (of this particular quality) reaching any

depth along the axis of the beam can be read immediately in terms of the amount which reaches the skin Fig 56 is the so-called isodose chart for this same beam of radiation, developed from measurements made throughout the phantom The relative doses delivered anywhere in the beam can be seen at a glance If the dose delivered at the center of the field on the skin was one threshold dose (TD), the chart gives immediately the per cent TD at any point If the skin dose was more or less than 1 TD, the dose at any other point is indicated as the percentage of this

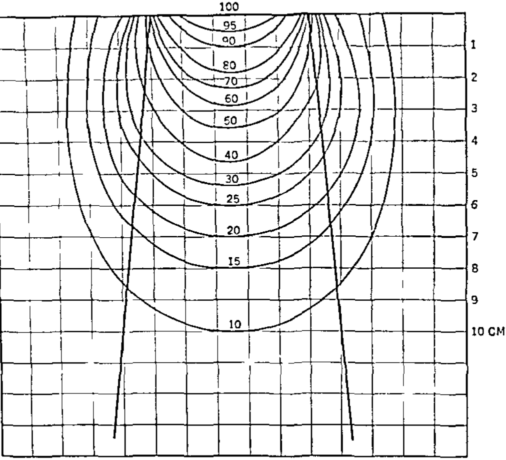


FIG 56 —Typical isodose chart 125 kv peak 25 cm T-S distance 3 mm Al filter 25 sq cm field

In Chapter XI the question of errors inherent in thimble chambers was discussed and it was stated that for accurately determining the surface and depth doses it is necessary to use a chamber of the extrapolation type

Factors Influencing Dosage —The effect of various physical factors on the amount of radiation delivered by the x-ray tube influences the amount of radiation delivered within the depths of the tissues The factors to be considered are voltage filter target skin distance, size of irradiated area milliamperes and time Instead of the last two the

roentgens per minute may be stated. Changing any of these three does not affect the relation between surface and depth dose; the amount of radiation delivered within the tissues varies in the same way as that delivered on the skin. Changes in the first four, however, bring about changes in the *relative* depth dose; that is, if any of these were altered in the specifications of Figs. 55 and 56, the curves would be different. The effect of each of these factors is independent of all the others, so that they may be considered separately. They will be taken up in turn.

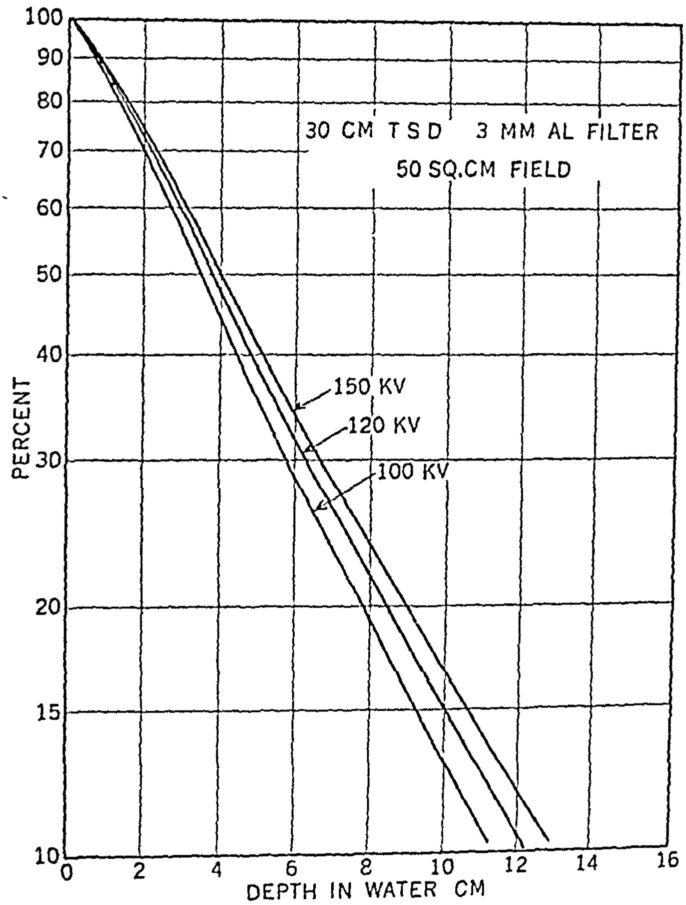


FIG 57.—Curves showing variation in percentage depth dose with voltage

1. *Voltage.*—With increase in voltage, the quantity of radiation emitted by the x-ray tube increases markedly, and the quality is changed by an increase in the proportion of shorter wave-length radiation, so that the average penetration of the whole beam is greater Fig. 57 shows depth dose curves for three voltages, 100, 120, and 150 kv., all others factors being the same Cutaneous lesions are not as a rule 2 cm. below the surface of the skin and at this depth there is no essential difference in the depth dose curves for these three voltages. There is at present no simple formula by means of which the depth

dose can be calculated for one voltage when those for another are known, it is necessary to measure them in each case

2 *Filter* — An increase in the filtration employed diminishes the quantity of radiation available, and at the same time alters the quality of the useful beam A thicker filter produces apparently the same effect on quality as a higher voltage it supplies more penetrating radiation, and hence an increase in the relative depth dose But whereas

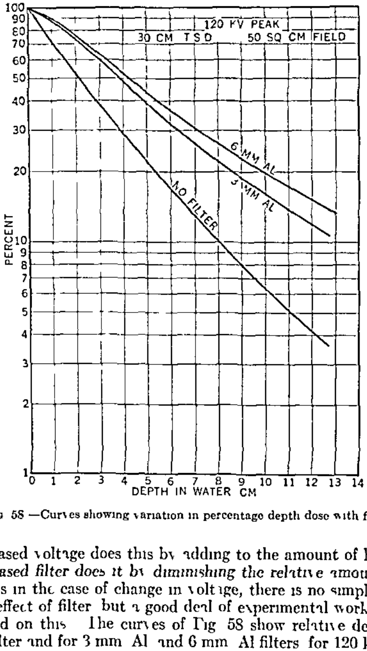


Fig 58 —Curves showing variation in percentage depth dose with filter

an increased voltage does this by adding to the amount of hard rays *an increased filter does it by diminishing the relative amount of soft* rays As in the case of change in voltage, there is no simple formula for the effect of filter but a good deal of experimental work has been published on this The curves of Fig 58 show relative depth doses for no filter and for 3 mm Al and 6 mm Al filters for 120 kv 50 sq cm area 30 cm target-skin distance These values should not be accepted as applying very closely to any particular installation For

low voltages and little or no filter, the construction and wall thickness of the individual tubes, and the type of rectification, may play considerable rôles.

It must be remembered that the addition of filter reduces the quantity of radiation available especially low voltage set-ups. The gain in depth dose indicated by these curves is at the expense of intensity; that is, in order to deliver a given amount of radiation into the tissues, a longer exposure is necessary when the filter is used.

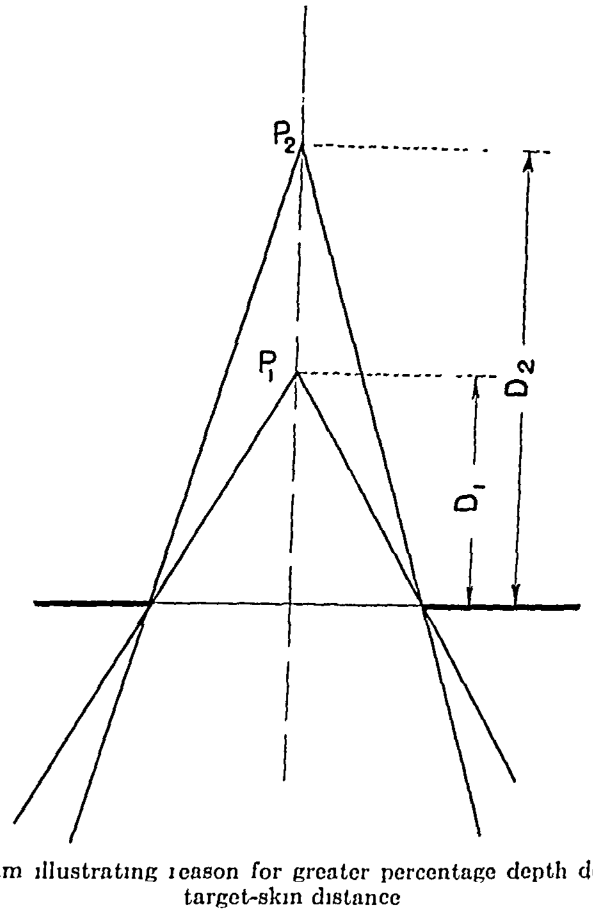


FIG 59 —Diagram illustrating reason for greater percentage depth dose with greater target-skin distance

3. *Target-skin Distance.*—It has been seen that increasing the voltage or the filter increases the depth dose by changing the quality of the radiation, in the first case by actually adding more penetrating radiation and in the second by eliminating more of the soft rays Increasing the target-skin distance also increases the depth dose, but does it on a purely geometrical basis, without in any way affecting the quality of the radiation This is easily seen from Fig 59 P_1 and P_2 represent two point sources of radiation, at distances D_1 and D_2 from the skin where a diaphragm limits each beam to the same area. On passing into the tissue, the beam from P_1 spreads out much more widely than that from P_2 Obviously if the amount of radiation passing through

the skin were the same in the 2 cases, each square centimeter at a depth would receive a smaller portion of the total from P_1 than from P. In other words, the relative depth dose (in a single cubic centimeter at the center of the field) is greater for the source at the larger distance. The actual increase can be readily calculated by means of the inverse square law (See Chapter X) as shown in the following illustration.

Suppose points P_1 and P are located 20 and 50 cm. respectively from the skin, and the dose to be considered is at a depth of 10 cm. Both beams pass through a 10 × 10 cm. area on the skin. At the 10 cm. depth, the area covered by the nearer source will be $\frac{(20 + 10)}{20} \times 100$ = 215 sq. cm. That covered by the farther source will be $\frac{(50 + 10)}{50} \times 100$ = 144 sq. cm. Each cubic centimeter at the 10 cm. depth will receive $\frac{1}{215}$ of the total radiation from the nearer source (neglecting the variation in intensity within the field), and $\frac{1}{111}$ of that from the farther, or

$$\frac{\text{Depth dose for 50 cm. distance}}{\text{Depth dose for 20 cm. distance}} = \frac{1/144}{1/215} = \frac{215}{144} = 1.50$$

Evidently by increasing the target-skin distance from 20 to 50 cm., the percentage dose at 10 cm. has been increased by 50 per cent. But it must not be lost sight of that for an *actual* increase of 50 per cent, it is necessary that the same dose be delivered to the skin in both cases. To deliver the same dose from the 50 cm. distance as from the 20 cm. distance requires $\frac{(50)}{(20)^2}$ = 6.25 times as long an exposure. Table 13 gives relative depth doses for various target-skin distances for radiation at 120 kv., with 3 mm. Al filter, for a field of 50 sq. cm. The variation with distance is the same for all qualities of radiation and all fields.

TABLE 13.—VARIATION IN PERCENTAGE DEPTH DOSE IN WATER WITH TARGET SKIN DISTANCE. 120 KV. 3 MM. AL FILTER 50 SQ. CM. FIELD

Depth cm.	Target skin distance, cm.				
	20	30	40	50	60
	Percentage Depth Dose				
0	100	100	100	100	100
1	83	86	87	88	89
2	67	71	73	75	76
3	53	58	61	63	64
4	42	47	50	52	53
5	34	39	42	44	45
7	23	27	30	32	33
10	13	16	18	20	21

4. *Size of Irradiated Area.*—An increase in the size of the irradiated area on the skin increases the quantity of radiation arriving at any point within the beam, by increasing the amount scattered into the volume in question. The relative depth doses for a number of fields, for radiation at 120 kv. peak, 3 mm. Al filter, and 30 cm. target-skin distance, are given in Table 14.

Each of these changes is independent of all the others, and may be calculated separately. It is evident that if the amount of radiation delivered to the skin is known, the amount at any given point within the tissues may be obtained from the data here given (for the qualities of radiation discussed).

TABLE 14.—VARIATION IN PERCENTAGE DEPTH DOSES IN WATER WITH IRRADIATED AREA. 120 KV. PEAK 30 CM T-S DISTANCE 3 MM. AL FILTER

Depth, cm	Irradiated area, sq cm					
	10	25	50	75	100	200
			Percentage Depth Dose.			
0	100	100	100	100	100	100
1	81	83	86	87	88	90
2	63	67	71	72	74	76
3	49	53	58	60	62	64
4	37	42	47	49	51	55
5	29	34	39	41	43	47
7	19	23	27	29	31	35
10	9	12	16	18	19	21

Radium.—So far, nothing has been said about external irradiation from radium. The same general line of thought may be followed as in the case of x-rays; the same type of change results with alteration in distance, filter, etc. (The inverse square law does not hold in general, because the radium applicator is usually too large in comparison to the radium-skin distance to be considered as a point source.) There are only a few institutions, however, which have sufficient radium to do effective external irradiation of anything except very superficial lesions. In dermatologic conditions where it is desired to concentrate the radiation in the superficial tissues, small applicators close to the skin may be very useful. When plaques are used close to the skin there is very great variation in the intensity of radiation throughout even the first centimeter of tissue. In order to deliver adequate dosage to the deeper portions of a lesion of this thickness, it may be necessary to produce actual tissue destruction in the superficial parts.

INTERSTITIAL IRRADIATION.

As has been shown above, the determination of tissue doses delivered by external irradiation is quite direct, and may be done with a fair degree of accuracy. Calculations for interstitial irradiation are more difficult, and, of necessity, less accurate. There is much more diversity

among the sources used for interstitial irradiation than for external. They may be permanent or removable radon seeds of different sizes, or removable radium or radon needles in a great range of lengths and filtrations. Measurements with a small ionization chamber, such as were generally useful for external irradiation, are of no value for distances small in comparison with the size of the chamber, as is generally the case for interstitial dosage. It is necessary to determine the distribution of radiation around each type of source in an indirect manner. Even when this is known, if several sources are used together, they may be implanted unevenly in the tissues. However, in spite of all these difficulties it is usually possible to arrive at a fair approximation regarding the *minimum* dose delivered within a given volume. This is the dose it is necessary to regulate, since if cells receiving this amount of radiation are killed, those receiving more should also succumb.

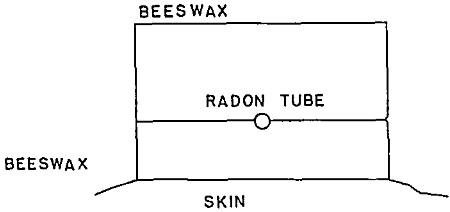


FIG. 60.—Diagram illustrating experimental determination of erythema reaction for interstitial irradiation.

Unit of Tissue Dose.—It is, of course, desirable to use the same unit in describing tissue doses from both interstitial and external irradiation. Naturally it is not practicable to introduce seeds or needles at specified positions under the skin and observe the resultant erythema, but a satisfactory approximation can be obtained by the following scheme. Beeswax has been shown to absorb and scatter radiation in very much the same manner as tissue. It can therefore be used as a tissue substitute in such a procedure as the following. A radon tube, of known length and filtration, is fastened in place on a piece of beeswax, about 10 cm. in diameter and of a known thickness. (See Fig. 60.) It is covered by another block of wax several centimeters thick and the whole strapped to the skin of the thigh as indicated. For each thickness of the lower block, trials are made with various exposures until the dose is found which produces the threshold reaction. This is assumed to be the dose which would also produce the threshold reaction if it were buried in the tissue at the same distance beneath the skin as the wax supports it above. By this means the amount of

radiation is determined which is necessary to deliver a threshold dose to different distances within tissue, for a certain type of implant. Similar measurements can be made for other implants, and for greater distances. As an experimental method, however, this is not very satisfactory. In order to obtain precise values of the threshold dose, it is necessary to make many tests, and to observe them over periods of at least two months

It has, however, been found that certain other reactions can be used for the purpose. The most convenient of these are the bleaching of butter and the production of necrosis in the dorsal muscles of rabbits. Both of these methods are used within the same range of distances as the skin reactions, and the butter, in addition, can be used for distances up to several centimeters. As supplementary data for these longer distances, certain ionization measurements are of service.

It is not desirable to present here a detailed discussion of the experimental work. It is sufficient to say that data obtained by all these methods were in good agreement, and to present the practical results.

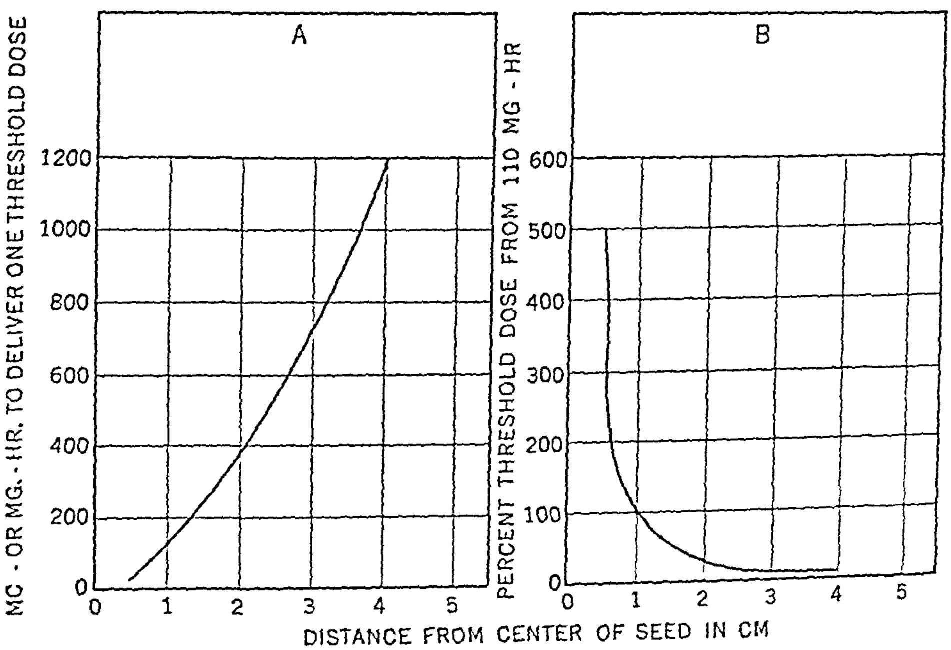


FIG 61 —Curves showing relation between distance and radiation dose for gold seed. *A*, Number of milligram- or millicurie-hours necessary to deliver one threshold dose at different distances *B*, Percentage of threshold dose at different distances for irradiation of 110 mg - or mc.-hr. or 0 85 mc destroyed

The curve of Fig. 61 *A* gives the number of millicurie- or milligram-hours necessary to deliver one threshold dose at different distances from a "gold seed," 4 mm. long, with a wall of 0 3 mm. gold (This is the standard type of seed, generally used.) Fig. 61 *B* gives the number of threshold doses delivered at different distances from 100 mc.-hr.,

or 0.8 mc destroyed,[1] from such an implant From these curves and within the given range of distances, all the necessary information can be obtained regarding dosage for this particular type of implant If the number of mc-hr is changed, the dose delivered at any given point will be changed in the same ratio However, it must be remembered that the distance at which a given dose is delivered is not varied in the same manner For instance an exposure of 200 mc-hr will deliver two T D at 1 cm It will not however, deliver 1 T D at 2 cm but at the distance which receives 0.5 T D from 100 mc-hr, namely 1.4 cm

Effect of Filter —If either the filter or the length of the implant is changed, these curves are no longer applicable, but corrections must be applied The effect of change in filtration is shown in Table 15, for distances from 0.5 to 2 cm a filter of 0.5 mm gold or platinum being taken as standard For distances greater than half a centimeter, it is evident that there is little difference in the radiation from the various types of gold or platinum seeds (ranging from 0.2 to 0.5 mm in wall thickness) Half a millimeter of gold cuts off all the beta rays and the thinner gold filters sometimes used transmit only a small proportion of them which are all absorbed in less than a centimeter of tissue However the less dense materials shown in the second part of the table transmit larger percentages of beta rays and also of soft gamma rays so that even up to 2 cm there are appreciable differences in the doses from these and the gold-filtered implants

TABLE 15 —VARIATION IN QUANTITY OF RADIATION DELIVERED AT DIFFERENT DISTANCES IN TISSUE WITH VARIATION IN FILTER (Quimby courtesy of Am Jour Roentgenol and Radium Therapy)

Distance in mm from center of implant	Percentage of radiation delivered					
	Filter					
	Gold or platinum			Steel brass or monel		Glass seed
	0.2 mm	0.3 mm	0.5 mm	0.25 mm	0.5 mm	
Surface of implant	135	116	100	327	164	3670
5	111	105	100	142	124	214
7	105	103	100	127	119	167
10	105	103	100	125	118	145
15	105	103	100	124	118	135
20	105	103	100	124	118	135

Effect of Length —The length of the implant is a very important factor For a given number of mc- or mg hr the longer the radiating source the shorter the distance at which a given dose is delivered by a given implant or conversely the greater the amount of radiation necessary to deliver one threshold dose at a given distance In Table 16 are shown the percentages of the threshold dose delivered at different distances in tissue by needles of different lengths for an irradiation of 133 mc-hr or 1 mc destroyed the filter being 0.5 mm gold

[1] See Chapter IX for definitions of these terms

TABLE 16 —PERCENTAGES OF THRESHOLD DOSE DELIVERED AT DIFFERENT DISTANCES FROM NEEDLES OF VARIOUS LENGTHS, FOR IRRADIATION OF 133 MC - OR MG -HR (1 MC DESTROYED) FILTER, 0 5 MM GOLD OR PLATINUM. (Quimby, courtesy of Am Jour. Roentgenol and Radium Therapy.)

Distance* cm	Percentage threshold dose					
	0.5 cm needle	1 0 cm needle	2 0 cm needle	4 0 cm needle	6 0 cm needle.	8 0 cm needle
0 5	400	270	195	130	90	65
1 0	100	78	67	51	40	30
1 5	41	36	32	27	23	19
2 0	28	23	20	18	16	13
3 0	14	12	11	9	8	7
4 0	7	6	6	5	5	4

* Distances all measured along a line perpendicular to the needle at its center

While the distance at which a given dose is delivered by a given quantity of radiation varies considerably with the length of the source, it should be mentioned that the total volume which receives a specified minimum dose has been shown to vary very little. For a short implant, the volume receiving the specified dose is practically spherical, for a long one, it is more nearly in the form of an elongated ellipsoid

Standards for the determination of dosage of gamma rays under different conditions are available. There are no comparable exact methods of measuring beta ray dosages The radiologist employs almost exclusively gamma radiations. The dermatologist employs both gamma and beta rays in the treatment of various skin diseases, including the cutaneous neoplasms.

Formerly radium dosage was based on the product of quantity of radium or radon employed and the time it was used. The dosage was expressed in milligram-hours in the case of radium or millicurie-hours in the case of radon. Expressing dosage in this manner carries little meaning. The distance, the filter, the shape and size of the applicator should be known.

Due largely to the work of Paterson and Parker, gamma ray dosages can now be expressed with almost the same accuracy as x-ray dosage The unit of measurement is the roentgen and the erythema dose for gamma rays is 1000 r. For most conditions even the filter and the distance of the radium from the lesion have been standardized. It has been determined that the quantity of gamma radiation received in one hour at a distance of 1 cm. from a point source containing 1 mgm. of radium element filtered through 0.5 mm. platinum is equivalent to 8 roentgens There are charts which can be consulted which make corrections for filters, distances and arrangements and sizes of needles or tubes Dosage can be simply expressed by use of the following formula

$$\text{Dose} = \frac{8 \times \text{mgm of radium} \times \text{hours}}{(\text{dist in cm})^2} \text{ roentgen}$$

The basis for radon dosage is different in that radon is undergoing constant decay Each day the activity of radon is decreased by 16 5

per cent and in 3 83 days the activity has decreased by one half One millicurie of radon in the course of its complete decay gives off 133 3 millicuries or expressed differently, 1 millicurie destroyed is equivalent to 133 3 millicurie hours The radiation effect is just like that obtained from 1 mgm of radium for 133 3 hours or 133 3 mgm of radium for one hour

It must be emphasized that the tissue dosage varies with the area irradiated Thus different biologic effects are obtained with the same quantity of radium when it is employed on the surface of the skin in the cavities of the body or interstitially At the present time radium dosage is not simply or accurately determined There is still much empiricism in determining the dose of radium or radon This is particularly true of beta-ray therapy

BIBLIOGRAPHY

FAILLA G and QUIMBY EDITH H The Economics of Dosimetry in Radiotherapy Am Jour Roentgenol and Rad Ther 10 944 1923

FRIEDRICH W Measurement of Gamma Rays Am Jour Roentgenol 40 69 1938

GREBE L and MARTIUS H Tabellen zur Dosierung der Roentgen trahlen Strahlen therapie Sonderband XIV 1930

KROENIG B and FRIEDRICH W The Principles of Physics and Biology of Radiation Therapy English Translation by Henry Schmitz New York Rebman Company 1922

MARTIN HAYES E QUIMBY EDITH H and PACK GEORGE T Calculations of Tissue Dosage in Radiation Therapy Am Jour Roentgenol and Rad Ther 25 490 1931

PATERSON R and PARKER H M Dosage System for Gamma Ray Therapy I Brit Jour Radiol 7 592 1934

——— Dosage System for Interstitial Radium Therapy Brit Jour Radiol 11 252 1938

QUIMBY EDITH H Physical Factors in Interstitial Radium Therapy Am Jour Roentgenol and Rad Ther 33 306 1935

QUIMBY EDITH H Tissue Dosage in Radiation Therapy The Cyclopedia of Medicine (Piersol) 10 722 1937

QUIMBY EDITH H COPELAND M M and WOODS R C The Distribution of Roentgen Rays Within the Human Body Am Jour Roentgenol and Rad Ther 32 534 1934

QUIMBY EDITH H and McNATTIN R F The Change in Quality of Roentgen Rays on Passing Through Tissue Am Jour Roentgenol and Rad Ther 28 236 1932

TAYLOR LAURISTON S and SINGER GEORGE Standard Absorption Curves for Specifying the Quality of X radiation Bureau of Standards Research Paper RP666 1934

WEATHERWAX J L and ROBB CHARLES Water Phantom Intensity Measurements of Roentgen Rays Produced by 127 000 Volts Am Jour Roentgenol and Rad Ther 27 749 1932

CHAPTER XIII.

THE TIME-INTENSITY FACTOR AND TISSUE RECUPERATION.*

The Bunsen-Roscoe Law.—In the early days of radiation therapy it was generally accepted that the effect produced depended only on the quantity of radiation administered, the intensity of the irradiation and time of its application being insignificant. Early x-ray doses were stated in terms of milliampere-minutes—and even at present some radiologists state gamma-ray doses in terms of milligram-hours. It was assumed that the so-called Bunsen-Roscoe law, or reciprocity law, was followed. This law, as announced by Bunsen and Roscoe in 1862, applied to the darkening of photographic papers by light, and stated that equal products of intensity and time produced equal darkening, in papers of equal sensitivity.

It would hardly be expected that a photographic paper and a living cell would behave in the same manner. The very fact that life processes were going on should have weight. Living tissues resist the action of injurious agents, and if this action is applied slowly, it might be expected that resistance would be more effective.

Protraction and Fractionation of Irradiation.—As a matter of fact, it has been known for some years that, in general, if a given amount of radiation is administered slowly, either by continuous irradiation of low intensity, or in fractions with rest periods of some hours or days between treatments, it is less effective in producing tissue changes than if it is delivered continuously at high intensity. There are evidently two aspects to the question: (1) the effect of *protraction* of irradiation, or the use of low intensity, and (2) the effect of *fractionation*, or the interposition of rest periods between treatments. Of course the individual treatments in the fractionated scheme may be of low or high intensity, with possible variation in results.

Biological Experimentation—*Protraction.*—Much biological experimentation has been done on the question of protraction, many different organisms and human subjects having been used. The cell is a living unit which is continuously growing, pursuing a specific function and undergoing the processes of metabolism. It can adjust itself to changes in its environment. It can recover from injury if not damaged beyond repair. The ability of the injured cell to adjust itself after injury is particularly noticeable after irradiation. Different cells recover in

* In the last edition, this chapter was revised by Dr Edith H. Quimby Some of the material added by Dr Quimby has been retained in this edition.

varying degrees following damage by rays of different wave lengths Different living substances such as seeds, fly eggs human skin, animal tissues, etc , respond differently to the effect of protraction or fractionation The practical significance of this is that information obtained with one group of cells or with one biologic test object cannot be applied to another

If a given amount of radiation is administered rapidly the effect on the tissue is more pronounced than when it is administered slowly by either fractionating the exposure or lowering the intensity There will be recovery of the tissues provided the dose is not a lethal one No appreciable biologic difference will be noted if the total dose of say 1000 r is given in one minute or in five minutes But if 1000 r is given in one instance in one minute and in another it is administered at the rate of 5 r per minute then there will be a different biologic reaction Holthusen and Braun have published curves to show differences in the production of erythema by using different intensities of radiation Others especially Quimby and MacComb Miescher, Mutscheller Meyer and Lee have studied this problem Data pertaining to low voltage unfiltered x-rays were published by us with the collaboration of Mutscheller A sharp erythema was observed in an area 2 by 2 cm when a dose of 435 r of unfiltered low voltage (52 kv) x-rays was administered in one minute When the intensity was reduced to 12 1 r per minute it took 910 r to obtain an erythema of equal intensity

The exact reason for this difference in biologic reaction with differences in intensity is not known Since healing is dependent upon time it is reasonable to assume that the decrease in effectiveness of radiation with lower intensities is due to healing or recovery during the irradiation

This question is of clinical importance Some radiologists insist that better results are obtained if radiation is administered at a very low rate (2 to 4 r per minute) Others feel that whether radiation is given at the rate of 4 or 40 r per minute, the time is still short in comparison to the life cycle of the cell and the result should be the same

Tissue Recuperation — Another way of stating the fact that radiation of lower intensity produces a less marked result is to say that the tissues will tolerate a larger dose of radiation if it is administered slowly It is also true that they will tolerate more if it is administered in fractions This must be because of recovery processes If these processes were the same for all tissues varying the rate of administration of radiation would be of no clinical significance By protracting or fractionating the radiation greater doses could be administered the normal tissues would tolerate more, but so would the diseased cells, and the final result would be the same However it has been found clinically that in many types of malignant tissue, it is possible by dividing the doses to produce regression of the lesion without marked permanent damage to the normal structures, whereas this was usually impossible

with a single massive dose. This means that recuperation must proceed more rapidly in the normal than in the diseased tissues.

Experiments on Human Skin.—In this regard, only observations on human subjects have any value clinically. Studies regarding *fractionation* are easier to make than those regarding *protraction,* and will be discussed first. Such studies have been mainly conducted on the skin reaction, because of its ease of observation It is, moreover, important, since in much radiation therapy the limit of skin tolerance is the limit of the radiation which can be administered.

After a sublethal dose of x-rays has been applied, how long does it take the cells to recover? The recovery rate was first described by Kingery and for over a decade his ideas of the rate of partial recovery of cells injured by x-rays were accepted. Kingery supposed that irradiation produced some hypothetical decomposition product in the tissue and that recovery would be in direct ratio to elimination of this product. On clinical observations Kingery determined that skin receiving one erythema dose of low voltage unfiltered x-rays recovered in three weeks. It was therefore calculated that if a certain dose is administered and 18 per cent of that amount is given daily, the tissues would remain at the "saturation" point. Others determined that for high voltage heavily filtered x-rays the factor of 6 per cent was employed. Pfahler and Weatherwax extended the use of the saturation method. The works of Coutard showed that better results in the treatment of carcinoma of the larynx could be obtained if the total dose could be divided over a period of approximately one month. Over this period of time a much greater dose could be tolerated by the tissues than if it was given at one sitting.

Quimby and MacComb and Reisner approached the problem from a different view point. They administered a single dose of x-rays necessary to produce a visible reaction, then the amount which was necessary to produce the same reaction when the dose was divided into 2, 3, 5, 7, etc , equal daily irradiations. These tests showed that recovery is much more rapid the first day after irradiation than during subsequent days The reader is referred to the article by Mutscheller for a full discussion of this question concerning recovery function of irradiated tissues. It has been found that different types of cells have different recovery rates. This serves as a basis for fractional dose therapy.

In tumor therapy, fractionation offers a decided advantage over massive therapy and all the experimental data on tissue recovery after irradiation should serve as final evidence of the advantages of often-repeated small doses of rays over a single intensive dose. Tumor cells and skin cells recover at different rates After each irradiation all the cells recover to some extent, but the skin more than the diseased tissue Finally a state is reached in which the damaged skin cells recover and the tumor cannot regenerate

Saturation Technic.—It is interesting, in the light of the experiments just described, to return to the "saturation technic." Here, ordinarily

an initial dose slightly less than the threshold is followed by small daily increments It is apparent that recuperation from the first dose would always be greater than that indicated by the constant factor assumed for this technic Successive doses would be recovered from less and less until the recuperation from the accumulated dose might be even less than the saturation figure That this is true is indicated by the following observations When saturation technic is used for high voltage, heavily filtered radiation, a skin reaction is seldom observed On the other hand for very soft radiation it has been found that visible effects are produced when the dose is theoretically below the saturation point This would be expected if the recuperation factor used were somewhat greater than the correct one for the last part of the curve even if it were less than the correct one for the first few days

BIBLIOGRAPHY

ALBERTI W and POLITZER G Das zweckmässige Intervall bei mehrzeitiger Bestrahlung maligner Tumoren Strahlentherapie **21** 535 1926

ANCEL P and VINTEMBERGER P Sur la radiosensibilité des cellules en caryokinèse Compt rend Soc de Biol **92** 956 1925

BOVIE W T A Law of the Relation Between Exposure and Biological Effect of Radiation Jour Cancer Research **10** 161 1926

BUNSEN R and ROSCOE H E Photochemische Untersuchungen VI Abhandlung Meterologische Lichtmessungen Ann d Phys u Chem **117** 529 1862

COX S F Tissue Culture and Its Applications to Radiological Problems—Time and Intensity Factors in Dosage Brit Jour Radiol **4** 111 1931

DUFFY J J ARNESON A N and VOKE E I The Rate of Recuperation of Human Skin Following Irradiation A Preliminary Report Radiology **23** 486 1934

HOFFMAN J C and REINHARD M C Considerations of the Variable Recovery Factor of Tissue *Radiology* **25** *698* **1935**

KINGERY LYLE B Saturation in Roentgen Therapy Its Estimation and Maintenance Preliminary Report Arch Derm and Syph **1** 423 1920

LEA D E The Dependence of the Biological Effect of Radiation on Intensity and Wave Length Am Jour Roentgenol **45** 605 1941

MACCOMB W S and QUIMBY EDITH H The Rate of Recovery of Human Skin from the Effects of Hard or Soft Roentgen Rays or Gamma Rays Radiology **27** 196 1936

MACKEE G M MUTSCHELLER A CIPOLLARO A C Time Factor in Irradiation Arch Dermat and Syph **47** 490 1943

MEYER W H The Co-Relation of Physical and Clinical Data in Radiation Therapy Radiology **32** 23 1939

MIESCHER G Tierexperimentelle Untersuchungen über den Einfluss der Fraktionierung auf den Spateffekt Acta radiol **16** 25 1935

MUTSCHELLER A Recovery Function of Irradiated Tissues A Theoretical and Experimental Study Radiology **38** 53 1942

PACK GEORGE T and QUIMBY EDITH H The Time-Intensity Factor in Irradiation Am Jour Roentgenol and Rad Ther **28** 650 1932

PFAHLER GEORGE E Further Observations on the Saturation Method in Roentgen Therapy as Applied to Deep seated Malignant Disease Am Jour Roentgenol and Rad Ther **20** 233 1928

QUIMBY EDITH H and MACCOMB W S Further Studies on the Rate of Recovery of Human Skin from the Effects of Roentgen or Gamma Ray Irradiation Radiology **29** 305 1937

REGAUD C and FERROUX R Influence du facteur temps sur la stérilization des lignées cellulaires normales et néoplasiques par la radiothérapie Acta Radiol Supplement **3** 107 1929

REISNER ALFRED Hauterythem und Roentgen Strahlung Ergebnisse der medizinischer Strahlenforschung **6** 1 1933

ROESLER H and HENSHAW P S The Influence of the Time Factor in the Irradiation of Drosophila Eggs Am Jour Cancer **16** 631 1932

CHAPTER XIV.

PROTECTION.*

Any agent as powerful in producing biological effects as x-rays or gamma rays is a potential danger. Persons exposed over long periods of time to radiations of even low intensity develop serious and lasting injuries. The actual amount of radiation which can be tolerated by the average individual cannot, of course, be determined accurately. By collecting data from a number of x-ray departments regarding the amounts which have been tolerated for long periods of time by technicians and radiologists, various investigators have arrived at conclusions that from 0.01 r to 0.1 r of total body radiation per day will produce no ill effects. Localized regions, such as the face or hands, could doubtless stand more.

The dangers are, of course, of two types, local and systemic. The possibilities of both must be borne in mind, and both must be guarded against.

Protection from X-rays.—It is necessary to surround x-ray tubes with sufficient lead (or other absorbing material) so that no radiation can escape except through the portal directed at the desired field on the patient. Even so, no one should be allowed to remain habitually in the room where treatment is being given, and this room must also be walled with protective material, because the patient's body scatters radiation out of the beam in all directions.

The Bureau of Standards has determined the amount of protection necessary for different types of installations. The following is quoted from the Bureau of Standards Handbook No. 15, on x-ray protection:

"Special Requirements for Apparatus of Class B. (*X*-ray installations for superficial therapy at voltages up to 140 kv. peak) *Protection from Direct Radiation.*

"A protective enclosure shall surround the entire x-ray tube so that direct radiation is shielded off in all directions by protective material of 2.5 mm. lead equivalent.

"This equivalent thickness may be reduced by an amount equal to the thickness of the lead lining of the room, except that in no case shall less than half of the lead protection be provided by the tube enclosure. In the case of x-ray tubes having built-in protection, or oil-immersed tubes in protective tanks, the protection shall be equivalent to that in Table 2. (Table 2 provides for 2.5 mm. of lead for 150 kv.) Where the built-in protection is insufficient, additional protection in any direction shall be added up to the required amount.

* In the last edition, this chapter was revised by Dr Edith H. Quimby. Some of the material added by Dr. Quimby has been retained in this edition

"When the x-ray tube is so arranged that the radiation can only be taken off in one fixed direction, a sheet of lead 2.5 mm. thick shall be placed in the path of the direct and useful beams, on the floor, wall, or ceiling opposite the diaphragm. This lead sheet shall extend 1 foot in all directions beyond the edge of the x-ray beam determined by the largest possible aperture in the tube enclosure.

When the x-ray tube is so arranged that radiation can be taken off in several directions, all parts of the room which may possibly be reached by the direct or useful beam of radiation shall be lined with sheet lead 2.5 mm. thick. The lead lining of this thickness shall extend 1 foot beyond the edge of the beam for any position of the tube enclosure with its largest possible diaphragm aperture. When there is any doubt as to the limits of the beam, the whole room should be lined with 2.5 mm. of lead. Protection from direct and useful radiation as indicated in the preceding paragraphs may be omitted only on sides adjacent to permanently unoccupied rooms or outside building walls.

"**Protection from Scattered Radiation.**—In the case of the preceding paragraphs, the entire remaining portions of the room shall be lined with sheet lead 1.5 mm. thick. All control apparatus shall be located in an adjacent room, or in a completely enclosed well-ventilated booth, lined with 2.5 mm. lead. Such a room or booth shall be provided with a suitably large protective glass window or windows of 2.5 mm. lead equivalent, so placed as to afford ready view of the patient and meters while the operator is in a normal and comfortable position.

"The tube container and treatment table should be so arranged that the useful beam points away from the technician's booth, offices, etc.

"When thermionic rectifiers are used, they shall be either placed in a separate room or surrounded by protective material of 0.1 mm. lead equivalent."

Protection from Radium Rays.—With regard to radium, the dangers are of two types. In handling tubes, needles, and small applicators, unless due caution is exercised, the fingers of the operator receive considerable exposure. This can be avoided by care always to use forceps and never touch a preparation with the fingers. Forceps with a shield similar to that of a fencing foil are desirable.

Even if one does not handle radium but is in its vicinity, there may be exposure to gamma rays, which are very penetrating. Much more lead is required to reduce these to a safe minimum than is the case with x rays. Fortunately the radium containers are small and can be kept in massive safes. The two main factors in gamma-ray protection are to place the radium as far away as possible and to use heavy protective material. The greater the distance, the less lead is necessary. Table 17 is developed from data obtained at the Memorial Hospital.

Carrying boxes for transporting radium about the hospital, should be lined with at least 1 cm. of lead, and have sufficiently long handles so that the radium is carried at or below knee level. Better still, more lead should be used and the carrier mounted on wheels. All manipula-

tions should be done behind lead blocks or benches, and should be carried out as rapidly as possible.

In handling radon, it should be remembered that there is very little beta- and gamma-ray activity during the first half hour, and, insofar as possible, manipulations should be carried out during that time, little protection then being necessary. Measurements are not usually made, however, until the condition of equilibrium has been reached, or the tubes have attained full strength. After this, radon tubes require the same protection as the corresponding amount of radium.

TABLE 17.—ADEQUATE LEAD PROTECTION AT VARIOUS DISTANCES FROM RADIUM SOURCES

Quantity of radium (0.5 mm Pt filtration) Gm.	Thickness of lead to give tolerance dose at the following distances from radium: Close up Cm	25 cm Cm	50 cm Cm	1 meter Cm	2 meters Cm	5 meters Cm	10 meters Cm	Tolerance distance with no lead Meters
0.05	9.5	5.5	2.5	0.5				1
0.2	11.5	8.5	5.5	2.5	0.5			2
0.5	13.0	10.5	7.5	4.5	2.0			3.5
1.0	14.5	12.0	9.0	6.0	3.0			4.5
2.0	15.5	13.5	10.5	7.5	4.5	1.0		6.5
5.0	17.0	15.5	12.5	9.5	6.5	2.5	0.5	10.5
10.0	18.0	17.0	14.0	11.0	8.0	4.0	1.5	14.5

Determination of Adequacy of Existing Protection.—The question often arises as to whether a given department or installation has adequate protection, or whether a given individual receives too much radiation in the course of his work. There are two simple methods of determining this. One, which requires no special apparatus, is a test with photographic films. A strip of film, wrapped in black paper, may be carried in a pocket, or posted at any questionable location, for a week or two. Standard films are prepared by exposing similar strips to known amounts of x-rays of the order of 0.01 r, 0.02 r, etc. (These very small amounts can be obtained by using long target-film distances. Thus a tube which gives 20 r per minute at 50 cm. will give at 200 cm 1.25 r per minute or 0.02 r per second.) All films, test and standard, are to be developed simultaneously, for the same length of time, in the same developer. By comparison on a light box one can readily determine whether a given test film is darker or lighter than a given standard. The method does not give an accurate evaluation of the amount of radiation received by the test film because of the fact that the photographic film is more sensitive to soft rays, of which the scattered radiation is largely composed. It does, however, furnish a satisfactory method of checking up on the question of protection. (See Chapter XI.)

Even more simple are the small "protection meters" which are available on the market. These are actually small ionization chambers with self-contained electroscopes, made about the size and shape of a fountain pen, so that they may be carried conveniently. They usually contain a scale calibrated in roentgens. Like the photographic method, these instruments do not give a very accurate measurement of the

radiation to which they are exposed, but do show readily whether it is within the safe range

Protection from Electrical Shock.—In addition to safeguarding personnel against excess irradiation the electrical hazards connected with any high voltage installation must be borne in mind. With the development of modern shockproof equipment, many of these dangers are removed. However, constant and rigid supervision of all electrical apparatus should be maintained. All cables, plugs and switches should be of the proper rating for the loads they are to carry, and fuses should be of the proper strength. Properly designed, quick-acting circuit breakers should always be interposed between the transformer and the supply circuit, set to trip at about 20 per cent overload on the primary. All high tension equipment must be made inaccessible by means of either an insulating or a grounded barrier, or placed in a separate room. In any case, an automatic switch should be so installed in the door that the transformer is shut off whenever the door is opened. With such a switch, it should be impossible to turn the transformer on again when the door is closed except from outside.

All permanent overhead high tension systems should be constructed of metal rods or tubes and placed at least 7.5 feet from the floor, unless they are in a completely inaccessible part of the room and should be adequately supported.

All water-coolers should be either made of metal or thoroughly protected against breakage and any glass gauges likewise shielded, when the cooler is in a treatment room.

Metal parts of apparatus, such as tube stands, transformer tanks, controls, etc., should be permanently grounded to a water pipe.

An additional precaution which it is advisable to take with air-cooled tubes is the mounting in the diaphragm of the tube container between the tube and the filter of a layer of asbestos board at least 1 mm thick to prevent a melted target from falling upon a patient.

Shockproof Apparatus.—Modern shockproof apparatus is also *x*-ray proof. The housing of *x*-ray tubes is generally lead lined, allowing *x*-rays to leave the apparatus only through the appropriate opening and these rays are directed to the area under treatment. Thus *x*-rays from shockproof apparatus designed for dermatologic purposes are generally directed downwards toward the floor. Occupants below the treatment room are protected by the thickness of the flooring, the material of which the flooring is built and the distance from the tube to the occupants of the floor below. The amount of scattering from the patient is negligible especially if small areas are being treated. Walls lined with lead of 0.1 mm thickness are more than adequate for shockproof installations of 100 kv or less.

The shockproof cables are not entirely safe. The rubber insulation does wear and the cables will break down. It is necessary for absolute protection that no part of the apparatus or the cables is in actual contact with the patient or with the operator during an exposure.

Even with shockproof apparatus the operator has to be constantly on the alert to prevent *x*-ray or electrical injuries.

BIBLIOGRAPHY

BARCLAY, A. E., and COX, S. Radiation Risks of the Roentgenologist; *Attempt to Measure Quantity of Roentgen Rays Used in Diagnosis and to Assess Dangers, Am. Jour. Roentgenol. and Rad. Ther.*, 19, 551, 1928.

FAILLA, G. Radium Protection, *Radiology*, 19, 12, 1932.

KAYE, G. W. C.: Fundamental Aspects of Roentgen Rays and the Protection of the Roentgen-Ray Worker, *Am. Jour. Roentgenol. and Rad. Ther.*, 18, 401, 1927.

KAYE, G. W. C., BELL, G. E., and BINKS, W. Protection of Radium Workers from Gamma Radiation, *Brit. Jour. Radiol.*, 8, 6, 1935.

MUTSCHELLER, A. Safety Standards of Protection Against *X*-ray Dangers, *Radiology*, 10, 468, 1928.

QUIMBY, EDITH H. A Method for the Study of Scattered and Secondary Radiation in *X*-ray and Radium Laboratories, *Radiology*, 7, 211, 1926.

QUIMBY, E. H., and POOL, J. Protection in Radiology, *Radiology*, 41, 272, 1943.

SIEVERT, R. M.: Einige Untersuchungen über Vorrichtungen zum Schutz gegen Röntgenstrahlen, *Acta radiol.*, 4, 61, 1925.

United States Department of Commerce. Bureau of Standards Handbook No. 15, *X*-ray Protection, 1931.

CHAPTER XV

ARITHMETICAL COMPUTATION OF X-RAY DOSAGE

THE arithmetical method of computing x-ray dosage at the surface of the skin was evolved by Shearer, Witherbee and Remer, and MacKee. The method served a useful purpose for many years and with modifications it is still useful. When one knows the quantity of radiation obtained with a given installation, it is possible by utilizing four well known laws or rules to determine the quantity of radiation when any change is made in the factors.

In any x-ray therapeutic technic there are four factors that are extremely important, namely, milliamperage, voltage, time and distance. If these constants are accurate and are maintained throughout the exposure, a definite quantity and quality of radiation will reach the skin. And assuming that no error is made, every time that these constants are used with the same apparatus, tube and instruments under the same working conditions, quantity and quality of radiation will be approximately the same.

Rules.—There are certain fundamental physical laws that apply to all electromagnetic waves emanating from a point source. These are:

1. The intensity of radiation varies as the square of the voltage.
2. The intensity of radiation varies as the milliamperage.
3. The intensity of radiation varies as the time.
4. The intensity of radiation varies inversely as the square of the distance.

In 1915 Shearer expressed these rules in the following formula:

$$\text{Intensity} = \frac{\text{milliamperage} \times \text{kilovoltage}^2 \times \text{time}}{\text{distance}^2}$$

more briefly it may be expressed as

$$I = \frac{Ma \times Kv^2 \times T}{D^2}$$

where I = intensity
Ma = milliamperage
Kv = kilovoltage
T = time of exposure
D = anode skin distance

It should be understood that arithmetical computation as here outlined pertains only to superficial therapeutic work with unfiltered x-rays, that the voltage range is from about 60 to about 150 kilovolts and that the estimation is for the dose that reaches the surface of the

skin and measured in air. It is important to realize that "distance" means from the anode to the skin, and not from the glass wall of the roentgen tube to the skin.

Intensity can be measured with satisfactory accuracy by any dermatologist or roentgenologist, after a little practice, with one of the standard ionization dosimeters in terms of roentgens (r). The milliamperage can be read directly from the two milliammeters. To ascertain the length of exposure a stopwatch is used. The distance can be measured in inches or in centimeters. The kilovoltage for each *x*-ray apparatus is usually determined by means of blunt points or 5-inch sphere gaps under standard conditions of pressure, temperature, and humidity. Therefore, with any given outfit the kilovoltage is obtained from the voltmeter.

It should be kept in mind that different tubes have different distances from target to glass wall, that the glass wall of different tubes varies in thickness and that the output from different *x*-ray machines, even when of the same type and from the same manufacturer, varies (MacKee and Cipollaro and others) Therefore, a set of factors or constants is accurate only for the given complete *x*-ray outfit.

Under these conditions, any of the constants may be changed and the dose arithmetically estimated. Such estimation is, of course, therapeutically meaningless without a biological standard or point of departure A standard may be obtained by producing erythema on human skin with a definite set of factors, which amount of radiation can be measured in roentgens. Such a standard is open to justifiable criticism, but for practical superficial work it is satisfactory.

Remer and Witherbee, and MacKee determined that the following constants, when used with their apparatus and tube, would evoke erythema on human skin of average radiosensitiveness: ma 3, kv 64 (approximate), time, five minutes; distance, 8 inches. This formula was accepted and used as a standard erythema formula by American dermatologists for many years It was called an arbitrary unit (the unfiltered skin unit, approximately 300 r) and it was used as a basis for arithmetical computation Those who desire to ascertain the details of the experimental work are referred to page 255 of the second edition of this book Now that it is known that such a formula is accurate only for one transformer, tube and set of instruments, and now that both skin effects and ionization dosimeters are used to check results, the arithmetical method as originally published is no longer employed.

Let us assume that a certain *x*-ray apparatus yields 300 r (measured in air) when the following factors are used: 3 ma , 100 kv , two minutes' exposure, and a skin focal distance of 8 inches No filter is employed and the area exposed is not less than 4 square cm ; 300 r measured in air with a calibrated Victoreen r meter has been accepted as the erythema dose as well as the epilating dose for unfiltered radiation. How, then, are arithmetical computations applicable?

In order to demonstrate the practical application of arithmetical computations, the following examples are given

What will the output be if the time is increased by one minute?

We will first determine the constant called K for the above apparatus which is equivalent to 300 r

$$K = \frac{3 \times 100^2 \times 2}{8^2}$$

$$K = 937.50$$

937.50 is a number which is derived by working out Shearer's formula using the above factors This number represents the erythema dose or 300 r

By increasing the time by one minute the output will be one and a half times the erythema dose, or 450 r

It is derived thus

$$\frac{3 \times 100^2 \times 3}{8^2} = 1406.25$$

$$1406.25 \div 937.50 = 1.5$$
$$1.5 \times 300\ r = 450\ r$$

What will be the dose if the voltage is doubled?

$$\frac{3 \times 200^2 \times 2}{8^2} = 3750$$

$$3750 \div 937.50 = 4$$
$$4 \times 300\ r = 1200\ r$$

By doubling the voltage the output will be 4 times the erythema dose, or 1200 r

What will the dose be if the milliamperage is doubled?

$$\frac{6 \times 100^2 \times 2}{8^2} = 1875$$

$$1875 \div 937.50 = 2$$
$$2 \times 300\ r = 600\ r$$

By doubling the milliamperage the output will be twice the erythema dose or 600 r

Suppose the distance is increased to 16 inches, what will the dose be?

$$\frac{3 \times 100^2 \times 2}{16^2} = 234.375$$

$$234.375 \div 937.50 = 0.25$$
$$0.25 \times 300\ r = 75\ r$$

By increasing the distance to 16 inches the output will be one quarter the erythema dose or 75 r

If the operator finds it more convenient to employ 2 milliamperes,

120 kilovolts, and a distance of 8 inches, how much time will be required for the administration of 1 skin unit?

$$\frac{2 \times 120^2 \times T}{8^2} = 937.50$$

T represents time in minutes.

$$\frac{28{,}800\ T}{64} = 937.50$$

$$T = 937.50 \times 64 \div 28{,}800$$
$$T = 2.08 \text{ minutes}$$

The time of 2 minutes and 4.8 seconds would be required to produce 300 r when using 120 kilovolts and 2 milliamperes.

These examples are sufficient to illustrate the practical application of the formula method for dosage determination.

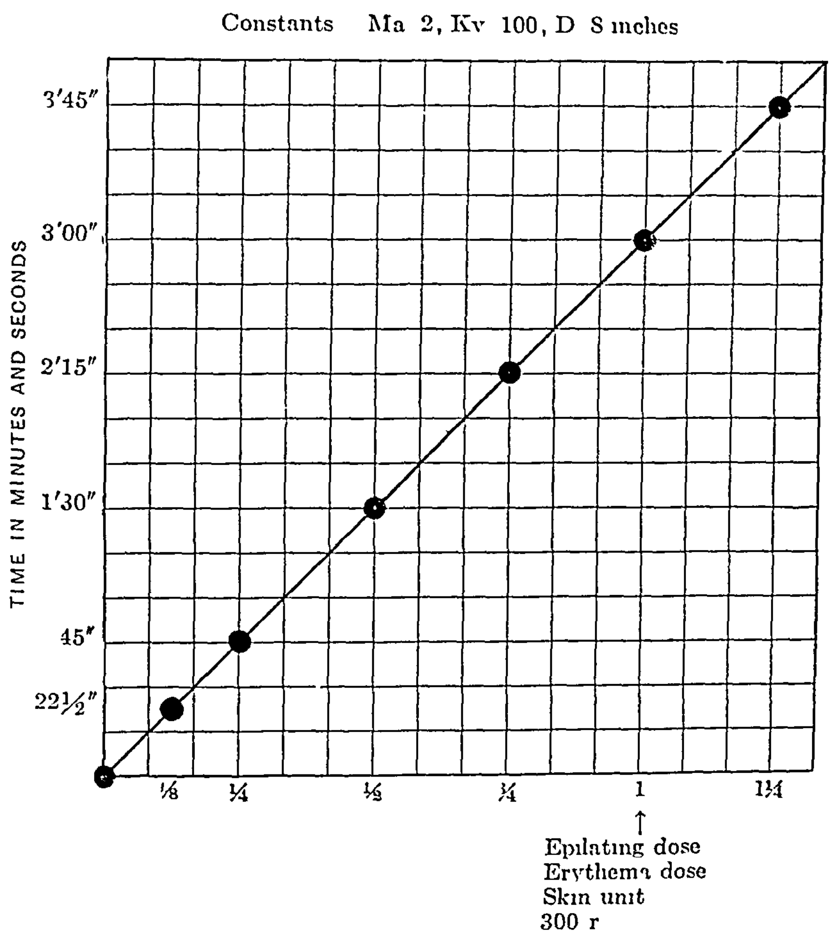


FIG 62.—Dose chart for unfiltered superficial therapy

Constants. Assuming that a given apparatus yields 300 r when the following factors are used, 2 Ma., 100 Kv., 8-inch skin anode distance

and an exposure of three minutes, then Fig 62 may be used to determine fractional parts of an erythema dose

Any set of constants desired by the operator, that will approximate the unfiltered erythema dose or skin unit, and that has been tested biologically and with an ionization dosimeter, may, of course, be the standard for his therapeutic technic From such a formula one may make a simple fractional dose chart by varying the time factor (Fig 62) This particular chart is from the last formula given above It will be noted that in the chart the time for the erythema dose is three minutes This chart has been used by the senior author for many years It is a wise plan for the beginner to decide on a formula, standardize it by skin effects and by ionization, and not change any constant except the time factor for the purpose of increasing or decreasing the dose The above-mentioned chart indicates the erythema dose or unfiltered skin unit and fractions thereof, obtained simply by altering the time factor in accordance with the law given at the beginning of this chapter It is a good plan to place such a chart on the switchboard It might be interjected that the skin unit, erythema dose, and the epilating dose for scalp hair in children, when properly standardized, are the same The skin unit will effect erythema of the skin of the body but not of the scalp If the operator desires to vary voltage, or to alter the distance factor, or the milliamperage, the approximate resulting surface dose may be ascertained by arithmetical computation

Possibility of Error —Arithmetical computation is susceptible of gross error The beginner is advised to avoid it except for the purpose of obtaining a set of constants When a formula has been selected or altered, it should be tested by ionization and biologically on the operator's skin before the technic is employed therapeutically The several sources of error are herewith appended

1 *Arithmetical* —The operator may not be an expert mathematician Lack of mathematical ability and an attempt to do the work quickly, may lead to errors

2 *Spark Gap* —It has been the custom for many to consider voltage and spark-gap lengths as synonymous Such assumption is correct only when the relation between voltage and spark gap is properly interpreted For instance, 64 kv are required to spark over a 3 inch point gap whereas 100 kv are required to spark over a 6 inch gap It is obvious that doubling the spark gap does not double the voltage Therefore, spark gap lengths, used for arithmetical computation, are inaccurate unless necessary corrections are made

Spark gap estimation of voltage is accurate for practical purposes when done by an expert using sphere gaps It is usually the basis for voltage calibration Discrepancies are noted in the estimation of spark gap lengths by different operators The readings vary with gaps of various types and with spheres of different dimensions There may be some variation between comparative spark-over values with

apparatus of various types. Finally, temperature, humidity, dirt and altitude, affect spark-over values. Over 80 kilovolts, 5-inch spheres instead of blunt point gaps give more accurate readings. The spheres should be kept dry and polished. Fig. 63 illustrates the differences in sparking voltages with point and sphere gaps without correction for altitude, temperature or humidity.

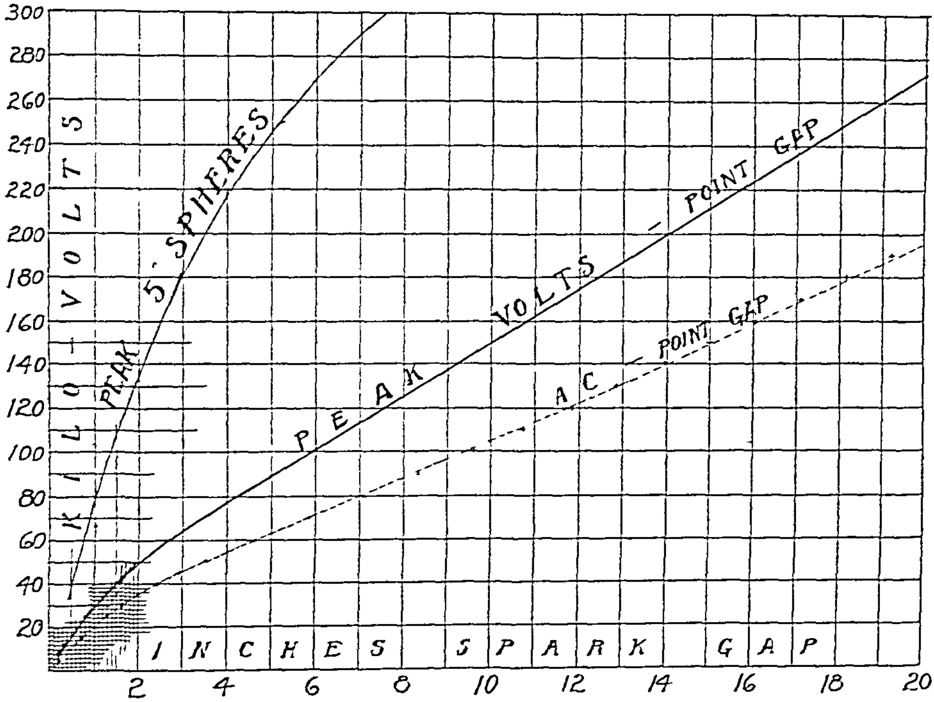


FIG 63.

3. *Voltmeter.*—The voltmeter on x-ray apparatus records the voltage applied to the primary of the transformer. It does not measure the kilovoltage in the secondary circuit; that is, the voltage applied to the x-ray tube; although many modern shockproof apparatus are so calibrated as to indicate the voltage in the secondary circuit. This calibration may be accomplished in various ways, but it is usually done by means of the spark gap. Five-inch spheres are used because they are more accurate than blunt points. Calibrations may be obtained in the following manner:

The spark-gap length is set and accurately measured with calipers A definite amount of current (assume 2 milliamperes) is then passed through the x-ray tube and voltage is increased until a small spark jumps the gap. Voltage and milliamperage are maintained and the gap widened. The terminals of the gap are now very slowly closed until a spark jumps. This is done many times in order to avoid the temporary effect of surges, line fluctuations, etc. Then the voltmeter reading is taken. Assume that it is 90 for a 6 inch point gap at sea level with average temperature and humidity, or equivalent length between

spheres of any given size This combination is compared with voltage charts supplied by manufacturers or physicists such, for instance, as Fig 63 which was made by Mr H D Garretson from data obtained from *Transactions of the American Institute of Electrical Engineers* 37, 1801, 1918 The peak voltage is seen to be 100 kilovolts

For the given apparatus, therefore, a voltmeter reading of 90, with 2 milliamperes of current, represents secondary peak kilovoltage of 100, and this voltmeter reading, on the same apparatus with the same amount of current, will represent 100 kilovolts regardless of alterations in heat, humidity or altitude In this manner voltmeter readings, in terms of secondary voltage, are obtained for every practical combination of spark gap length and milliamperage The use of point gaps as described above is not an accurate means of determining high tension voltage but it is practical and sufficiently accurate for dermatologic roentgenotherapy The use of movable sphere gaps determines high voltages with greater accuracy

Voltmeter readings must be tabulated in relation to both spark gap and current They are valueless for spark gap or voltage alone As an example, assume a combination of 2 milliamperes, 6 inch point gap and primary voltage 92 Now increase the milliamperage to 3 maintain the same gap, and the voltmeter will register 100 If milliamperage is increased to 4 and a spark is made to jump across the gap, the voltmeter will read 104 In other words, with increased current greater primary voltage is required to maintain secondary voltage There will be greater variation in this respect with rheostat than with autotransformer control The above figures were obtained with a combination autotransformer and small fixed resistance control

It is necessary, therefore, to calibrate for every practical combination of voltage and milliamperage that the operator is likely to require If the voltmeter is repaired or changed, a recalibration is necessary

The beginner must understand when discussing *x* ray technic that voltage means the voltage that is applied to the tube—the kilovoltage not the voltage that is applied to the apparatus, in other words, secondary and not primary voltage, and that the voltmeter measures primary voltage Therefore, the numerals on the voltmeter cannot be used for arithmetical computation The voltage factor must be expressed in kilovolts Furthermore when the apparatus is mechanically rectified, the term voltage used by roentgenologists refers to peak or crest voltage, not the A C voltage or mean voltage

4 *Apparatus of Different Type* —For a number of years all transformers used by dermatologists were of similar design, and even when obtained from various commercial concerns the output was approximately the same Now, however, there are a number of new standard types in addition to the old standard type, which is being used and will continue to be used by dermatologists for a long time Hence some types of apparatus have one transformer and a single mechanical rectifying switch Others are of the twin type with two transformers

and two rectifying switches. Rectifying switches may have angular or spherical metallic electrodes Some machines are equipped with a rheostat, others with an autotransformer and still others have both. Then there is the booster type. Finally, there is kenotron rectification with the number of tubes ranging from one to eight.

Without going into further detail, suffice it to state that the output is different for machines of the same type from the same and different manufacturers. Therefore, voltmeter, spark gap or other calibrations for one machine may not be correct for another apparatus.

5. *Erythema Dose.*—There is no absolute standard for the erythema dose. There are many reasons for this lack of standardization. The amount of radiation required for an erythema varies with sex, age, location, etc. Also, there is no standard tint or accepted amount of erythema. Furthermore, the toleration of the skin is considerable for different amounts of radiation, that is, a dose variation of 50 per cent or more may be difficult to detect by visible skin effects Erythema varies with the quality of radiation and with the type of apparatus used—whether it is rectified mechanically or by valve tubes. Large areas will react more vigorously than small areas. It is customary to use test areas about 1 inch square.

6. *Coolidge Tube Variations.*—This subject is discussed in Chapter V. Formerly the output from different Coolidge tubes showed a variation of over 50 per cent. Modern tubes vary much less in output.

Advice to the Beginner.—It should be obvious from the foregoing that it is unwise to attempt a universal technic based on arithmetical computation; that is, a definite, simple, standard technic that can be handed from one operator to another.

One may employ arithmetical computation advantageously by confining it to personal technic with one apparatus and one set of instruments However, it is necessary that the output from the apparatus be first determined by the ionization method so that the number of roentgens per minute for a certain set of factors is known. Then the operator may use a formula such as the one given in this chapter for the skin unit This should then be tested on the operator's skin If a slight erythema results the formula may be used as a standard for the particular apparatus—from which other formulæ may be computed if so desired. If no erythema results, it is necessary to test again. If the reaction is too sharp, another test should be made. When a formula that represents a dose that has been given, or is to be given, is handed from one operator to another, it should include the following information:

1. Type of apparatus
2. Peak voltage, milliamperage, time, and distance
3. Thickness and character of filter if one is used
4. The surface dose measured in roentgens without the effect of back scattering.

5 The size and number of fields exposed and the number of fields treated per day
6 Intensity delivered in a given time or rate of administration
7 The total cumulative dosage given
8 Skin—target distance
9 Duration of exposure
10 Interval between exposures

It has been customary to speak in terms of the erythema dose or the skin unit For instance, one dermatologist refers a patient to another in a distant city with a request that ¼ skin unit (or ¼ erythema dose) unfiltered x rays be applied to a certain area on a given date These terms have been universal in this country and represent something reasonably definite Assuming that each dermatologist has had his apparatus and technic properly checked and calibrated the dose given by each operator will be approximately the same—not by any means scientifically accurate, but sufficiently so for practical purposes

BIBLIOGRAPHY

Bachem Albert Principles of X Ray and Radium Dosage Chicago Bachem 1923 p 195

MacKee George M Arithmetical Computation of Roentgen Dosage Jour Cutan Dis 37 783 1919

MacKee George M and Cipollaro Anthony C The Roentgen Unit in Dermatology Arch Dermat and Syph 30 761 1934

McNiff W T College Physics 3d ed New York Fordham University Press 1912

Markley A J Point Gap Sparkover Variations and Their Effect on Dosage in Superficial Roentgen Ray Therapy Arch Dermat and Syph 14 704 1926

Remer John and Witherbee W D The Action of X Rays on Plate Pastille and Skin Am Jour Roentgenol 4 303 1917

Roberts Ffrangcon The Principles and Practice of X Ray Therapy London Lewis 1931

Robertson John K X Rays and X Ray Apparatus New York The Macmillan Company 1924 p 30

Shearer J S Measurements With the Coolidge Tube Am Jour Roentgenol 2 507 1914 1915

Shearer J S The Physical Aspect of Roentgen Ray Measurement and Dosage Am Jour Roentgenol 3 298 1916

CHAPTER XVI.

PRACTICAL *X*-RAY TECHNIC FOR THE BEGINNER.

It is assumed that the novice has read the preceding chapters and that modern equipment has been installed. We are now ready to establish a working technic for practical therapeutic purposes. Apparatus now in use by American dermatologists is for the most part of the mechanical rectification type, but each year a larger number of dermatologists are equipping office and clinic with apparatus of the kenotron type and shockproof installations. Therefore, the technic about to be described is applicable to both types of equipment. This chapter deals only with unfiltered *x*-rays, except where the filter is inherent in the apparatus, which is the type of radiation routinely employed by dermatologists.

The unit of measurement is the roentgen. All doses are expressed in terms of the internationally accepted unit.

Ionization dosimeters of the thimble type are available and their use can be mastered in a reasonable length of time by dermatologists or radiologists. They offer a quick method for the direct measurement of quantity of radiation. It is not recommended that every dermatologist purchase and use a dosimeter. Dermatologists in large and moderate-sized cities do well to have their equipment checked and calibrated periodically by a qualified physicist. Only a physicist can supply physically accurate measurements.

We have now to consider, from a purely practical standpoint, three possible technics, namely, direct, indirect, and a combination of the two.

DIRECT TECHNIC.

The so-called direct method consists of measuring the total quantity of *x*-rays reaching the skin by means of ionization dosimeters. The measurements are made in air without the effect of back scattering. Photographic radiometers are now obsolete. Some dosimeters are so constructed that the dose may be measured directly while it is being given. Others measure the quantity of radiation output per unit time. With special filters and an ionization dosimeter, the quality of an *x*-ray beam may be determined utilizing the principle of the half-value layer. Aluminum is the metal used for voltages generally employed by dermatologists.

INDIRECT TECHNIC.

The so-called indirect method of estimating roentgen dosage antedates all other schemes of measurement in practical work. The esti-

mation is made by means of voltage, milliamperage, time and anode skin distance Before the advent of the interrupterless transformer and the Coolidge tube, the method was exceedingly unreliable and gave way to the so-called direct technic (pastille and photographic radiometers, etc) The chief requisite of indirect technic is ability to control voltage, or ability to establish certain technical factors or constants and to maintain them or vary them at will Modern apparatus and instruments supply this demand reasonably well The indirect technic is used to some extent by American dermatologists, but it has given way largely to the so-called combined technic, as should be the case

COMBINED TECHNIC

By combined technic is meant indirect technic which is frequently checked or controlled by ionization and skin effects Great advances have been made in the past few years and it is now possible to use ionization dosimeters without special knowledge of physics These instruments are sufficiently accurate and reliable With a little practice any dermatologist can use one Many dermatologists check the indirect technic biologically (skin effects) or with an ionization dosimeter, while others have the apparatus, instruments, tube and, in fact, the entire technic checked at regular intervals by a physicist We advocate periodic checking—yearly, or when any repairs or changes are made in the equipment This should be done by a physicist qualified to check quality and quantity by the ionization method Biologic checking (skin effects) is necessary to collaborate physical findings

In electrical or indirect measurement there are four factors which are of the greatest importance, namely, milliamperage voltage time and distance These are the factors or constants that establish the technic If we employ 2 milliamperes of current 100 kilovolts, a distance of 8 inches and an exposure of three minutes assuming that these factors remain constant throughout the exposure, a definite amount of radiation will reach the skin It is obvious that every time these constants are used with the same apparatus and tube, and the same working conditions, the same quantity and quality of radiation will be produced With different apparatus, even of the same manufacture different quantity and quality of radiations are produced Therefore iontoquantimetric measurements obtained with one *x*-ray apparatus cannot be applied to another The first step in this technic is to decide upon what factors are to be used routinely Electrical factors which yield at least 75 to 100 r per minute are satisfactory At this rate an erythema or epilating dose may be obtained in three or four minutes

For routine work the authors have used the following approximate constants for many years ma 2 kv 100, time, approximately three minutes distance 8 inches (20 cm) from anode to skin Some

apparatus requires three minutes to produce 300 r, others require more or less time. After the operator has decided on routine constants, he checks them with an ionization meter as well as biologically, and then he may plot a simple dose chart by dividing the time factor (Fig. 62). This particular chart has been used many years by the senior writer. If the operator desires to do so, charts may be made that give the dose with various constants.

The method employed to obtain milliamperage and voltage depends upon whether the apparatus is rectified mechanically or by valve tubes. As a rule, valve-tube equipment and shockproof apparatus are not supplied with a spark gap. It is therefore necessary to employ the services of a physicist to obtain voltage and milliamperage and to calibrate the *x*-ray machine. Most shockproof machines have voltmeters which are calibrated for high tension circuits. The kilovolt and milliampere readings may be obtained directly from the meters installed on the control panel.

Those still using mechanically rectified machines will also do well to have their equipment calibrated and checked at least once a year by a physicist.

After these two factors have been established they must be maintained throughout the exposure. With the main control in the same position, one factor will probably not change unless the other does. If milliamperage increases, the voltage decreases and *vice versa*. Therefore all that is necessary, as a rule, is to hold milliamperage by adjustment of the filament control. It is, however, advisable to watch the voltmeter and if voltage decreases or increases without apparent change in milliamperage, the correction can be made by a slight readjustment of the main control.

Voltage Factor.—As intensity varies as the square of the voltage, it is obvious that voltage should be accurately determined. The voltmeter should be calibrated in terms of secondary voltage by the manufacturer or by a physicist. If this is impossible, the operator may calibrate the voltmeter by comparing its readings with the spark gap. This may be done with mechanical rectification without great danger of injuring the apparatus, but with kenotron rectification there is danger of puncturing one or several expensive kenotron tubes.

Current.—There should be two milliammeters, and they should always register alike.

Time.—The time is measured with a stopwatch. If the exposure is interrupted for any reason—refractory patient, trouble with apparatus—the number of seconds already utilized must be accurately determined and recorded.

Distance.—An error in distance will have a profound effect on dosage. It must be borne in mind that intensity varies inversely as the square of the distance and that, therefore, if the distance should be decreased one-half, the dose would be increased four times. By the term "distance" is meant the number of inches or centimeters between the

target and the skin. To establish this factor it is first necessary to measure the circumference of the tube from which the diameter and radius may be estimated. If, for instance, the circumference is 22 inches, the diameter will be 7 inches (7.0028 inches) and the radius 3½ inches. To obtain a skin target distance of 8 inches cut a piece of wood exactly 4½ inches and adjust the tube so that one end of the measuring stick touches the wall of the tube while the other extremity touches the lesion. Inasmuch as the circumference of different tubes varies, it is advisable for the operator to measure each tube.

In establishing distance it is important that the measuring stick touch the glass wall of the tube at the equator directly under the anode and also the skin directly in the center of the lesion. It seems superfluous to add that the distance must be accurately maintained during the entire exposure. But it is carelessness in this regard that causes many of the errors of roentgen therapy. It often happens that the part moves a little closer or a little farther away, or a little to one side, without attracting the attention of the operator. On one occasion we found that the tube-holder had slid down the stand so that the skin target distance was reduced from 8 to 6 inches. One must be cognizant of these possibilities and guard against them. The tube and tube-holder should be firmly fixed. The patient must understand the necessity of maintaining position and even with the patient's cooperation the operator or the assistant should watch the part for motion. To insure against change of position some operators employ a small rubber suction cup or a piece of adhesive plaster fastened to the wall of the tube from which is suspended a string 4.5 inches long. At the lower end is attached a small ball made of very soft wood which comes in contact with the skin. Shockproof apparatus have mechanical appliances attached to the tube housing which serve to indicate the position of the anode and its distance from the surface to be treated. Finally, the part to be treated can be securely fixed by the use of sandbags, roller bandages, etc.

Ionization Standardization.—The milliamperage, voltage, time and distance factors have been obtained. It has also been determined that the erythema dose for unfiltered radiations is 300 r. How does the radiotherapist standardize his *x*-ray equipment by ionization? The most practical type of ionization dosimeter to use is the thimble type with a scale that is calibrated in roentgens. The chamber is exposed to a beam of *x* rays (in air) for a certain length of time. A reading is taken and the result is recorded as so many roentgens per minute. Let us say that an *x*-ray machine is allowed to run for thirty seconds. The factors were 100 kv., 3 ma., 8-inch chamber-anode distance, no filter used. The reading on the calibrated scale is 75. Under the above conditions the output is 75 r per thirty seconds or, as commonly expressed, 150 r per minute. The erythema dose for unfiltered radiation is 300 r; therefore to obtain erythema or epilation two minutes will be required. Care must be taken to state that this

dose does not include back scattering. It is measured in air and is an expression of dosage applied at the surface.

Biologic Standardization.—After the beginner has decided upon the set of factors or constants he desires to employ for routine therapeutic use, the technic should be tested biologically. This may be accomplished in various ways. Hazen standardizes by the mouse epilating dose which he finds to be six times the epilating or erythema dose for man. Krönig and Friedrich use frog larvæ. Wood uses rat tumor tissue; Packard uses *Drosophila* eggs; Arntzen and Krebs use peas; and Hoffmann uses protozoa. The popular method of standardizing surface intensity employed by dermatologists in practical work is by visible skin effects.

While the visible skin effect method is not sufficiently precise for scientific purposes, when properly done it is accurate and sensitive enough for practical purposes. Especially is this true for dermatoroentgenology.

The following features should be kept in mind:

1. Visible skin effects are but one phase of a complex biologic reaction, and must be so interpreted.

2. A visible effect produced by filtered *x*-rays will have a different significance from that produced by unfiltered radiation. With the former the reaction is deep, while with the latter it is comparatively superficial. However, this fact does not destroy the value of this method of standardizing in practical work.

3. There is no standard erythema dose that has been universally accepted; that is, no definite color, no set time for appearance or disappearance of erythema.

4. Skin tolerance varies with age, sex, amount of blood present, location, complexion, and the time intensity factor. Tissues will tolerate more radiation if given slowly than if given rapidly. There may also be inherent differences. More important, however, is the skin tolerance for different amounts of radiation. A quantitative difference of over 50 per cent may hardly be detectable by visible skin effects. MacKee and Cipollaro and others have pointed out that erythema is produced with a smaller number of roentgens if the radiation beam is "soft."

5. The method is most reliable when the reaction is very slight but, of course, definite. Care must be taken, in these slight reactions, not to confuse tanning or pigmentation with erythema. The exposed area should be examined every day or two and notes made relative to the time of appearance of the erythema; also its evolution and involution.

6. The size of the surface or port of entry makes considerable difference. This is due to scattered and secondary radiation originating in the tissue, some of which reaches the skin and adds to the surface effect of the primary beam. The amount of scattered radiation depends partly on the wave length of the primary beam and partly on the volume of tissue traversed by the primary radiation. The amount

is greater with short than with long wave lengths, and it increases with the size of the port of entry, and with the density of the tissue radiated

Bachem calls attention to the fact that scattering is increased with longer skin focal distance because with increase of distance the beam is more perpendicular and, therefore, more radiation enters the field with a corresponding increase of scattered radiation

Areas of about 1 square inch in size are usually employed by dermatologists to standardize the erythema dose There is not very much difference in visible skin effects, with the same dose of unfiltered x rays in areas ranging in size from 1 to 4 square inches There is a marked difference in visible skin effects between very small areas (split-pea-sized area) and fields 1 square inch in size or larger In accepting the erythema dose of 1 square inch of skin as a standard, it must be borne in mind that the effect will be increasingly greater for larger fields up to an area of about 8 inches square Also, that the effect is considerably less for minute areas (see article by MacKee, Mutscheller and Cipollaro)

Whenever a new set of constants is used, or a new tube is acquired, or the apparatus is changed, or the operator moves to a different altitude the technic should be checked by skin effects and by ionization There are many objections to every method of standardization The objections to standardization by visible skin effects are numerous, but at present it is the best biologic method for the average dermatologist to use Among the chief objections are the length of time required for the erythema to develop, difficulty of determining intensity of erythema absence of a universal standard for time of development and duration of erythema, and the fact that the skin of different persons and skin in various parts of the same person will react differently to the same dose The skin of some of the flexures, some of the flexor surfaces and of the face will in some adolescents and young adults, react to one-half the amount required for the same degree of reaction on other parts of the same person It is preferable therefore, to make a number of experiments on various parts of different persons and ascertain the dose required to effect the same degree of erythema under different conditions

It is necessary to have some standard Attempts have been made to standardize the erythema dose for superficial therapy It is the amount of radiation that will effect faint but definite erythema on a flexor surface of the average young adult It may be called the minimal erythema dose It has been designated as the skin unit This amount of radiation will cause temporary epilation of scalp hair in children without effecting erythema It is, therefore, also the epilating dose

The term erythema dose or skin unit (300 r for low voltage unfiltered x rays) while not being precise, nevertheless has a fairly definite meaning and it is popular among American dermatologists Dosage may therefore be expressed in terms of the erythema dose or skin

unit, and fractions or percentages thereof, or in roentgens. These terms are suitable when discussing generalities. At other times, it is advisable to enumerate all the constants, the type of apparatus, the number of roentgens, the type of ionization dosimeter used and, in fact, all working conditions.

Milliampere-minutes.—Not infrequently roentgenologists find it convenient to combine, by multiplication, the tube current in milliamperes and the time in minutes and express dosage in terms of milliampere-minutes. This method of recording and reporting dosage is lacking in accuracy and is obsolete.

Training.—When a physician desires to enter the field of roentgen therapy, he should go to one of the many institutions where a suitable course may be taken. Then he must acquire adequate knowledge about the diseases he is to treat. Apparatus is then purchased and standardized. If such training is impossible, the physician must depend first on a book for his knowledge and guidance. When the apparatus has been purchased and standardized, experiments should be made on the operator's own person as outlined in this chapter. It is well also to purchase a standard ionization dosimeter so that *x*-ray output may be measured in terms of roentgens. The first therapeutic attempts should be with small fractional doses, properly spaced, on diseases that are amenable to such treatment. At first, large doses should be limited to the treatment of epithelioma. We do not advise physicians to use *x*-rays or radium without adequate training in radiology and in the diagnosis and treatment of the diseases to be treated with these agents. Book knowledge or the ability to operate an *x*-ray machine does not constitute adequate training.

The Margin of Safety.—There is, undoubtedly, a definite biologic effect for any specific quality and quantity of *x*-rays, but such a statement is difficult to prove even in the experimental laboratory. In daily practice, in order to determine the biologic response, it is usually necessary to depend on phenomena that are visible to the unaided eye such, for instance, as visible skin effects, *i. e.*, erythema, dermatitis, epilation, etc.

If a small area of human skin is exposed to a sufficient quantity of radiation of given quality, a mild erythema will develop. It will appear a certain length of time after the exposure, develop to maximum intensity, and then gradually disappear. If a contiguous area of the same size is exposed to a 25 per cent larger dose of the same quality, the erythema will develop a trifle sooner, it will be slightly more intense and it will endure a little longer. The visible difference is apt to be slight and might be easily overlooked. Theoretically, the larger dose will be more likely to cause sequelæ because the biologic effect must be 25 per cent greater. Clinical observation, however, does not support this contention. While this type of skin tolerance is possibly more apparent than real, it does appear to provide a fortunate margin of safety.

A similar observation may be made on the scalps of children. The epilating dose may be increased 25 per cent or even more and the only visible effect, as a rule, is temporary loss of hair. A careful observer, however, will notice that with the larger dose the hair falls a little sooner, the epilation is a little more complete, and the regrowth of hair is slightly delayed. Of course, with still larger doses there will be erythema and permanent alopecia.

It is difficult to estimate accurately the dose by visible skin effects. The erythema dose or epilating dose can be determined in this manner and by utilizing contiguous areas of skin it is possible to compare the result with various sets of factors, various doses, etc. But if the reaction is greater in one area than in another it is impossible to state the per cent dose difference from the visible effects alone. The erythema dose for a given area, with definite quantity and quality, may be multiplied several times without the production of more than a mild second-degree reaction. This is especially true for old persons and for filtered radiation. Still larger doses will cause deep necrosis. The point to be emphasized is that it is difficult to decide from skin effects alone, whether the dose has been doubled, trebled, or quadrupled. Biologic reactions are exceedingly complex and visible skin effects must be carefully observed and interpreted. Even with contiguous areas of skin the effect may be modified by vascular, physiologic, anatomic, vasomotor, and pathologic variations. Nevertheless properly located contiguous areas of similar size will usually react exactly the same to the same quantity and quality of radiation, so far as can be determined with the unaided eye. It should be noted that we are discussing *x*-rays produced by voltage ranging from about 60 to about 150 kilovolts.

Naturally it is desirable to make a technic as accurate as possible. It is doubtful if 100 per cent accuracy in practice will be achieved until some simple, sensitive, accurate and reliable method for directly measuring the tube output is devised. More important than the mere measurement of surface dose is the effect of back scattering, volume dose and other unknown biologic effects from different qualities and quantities of *x*-rays. At present we have no simple means of accurately measuring and interpreting these biologic reactions. The technic outlined in this and the previous chapter has been criticized by some physicists and by many roentgenologists who are fairly capable physicists. For the most part this criticism has been constructive and justifiable but the critics do not fully appreciate the practical difficulties of the dermatologist. X-rays constitute the most essential single remedy in dermatology. This agent has been of great importance in the development of dermatology of which it is an integral part. A very large number of treatments is given daily, as many as 100 or more, by numerous assistants and technicians in a busy dermatologic office or clinic. The fees are often small. The dermatologist is exceedingly busy with many other phases of a dermatologic career

As a rule education in physics has been neglected. The technic must be sufficiently safe for practical dermatologic requirements, it must not be too complicated, it must not be too time-consuming and it should not be so expensive as to be prohibitive for the financially poor young dermatologist. Time, expense, convenience, etc., would be unworthy of consideration if a simple, safe technic were not available. Fortunately, one is available for the dermatologist.

A physicist can develop a technic that is associated with a high degree of accuracy. This is accomplished by the use of ionization methods, spectrometers, electrostatic voltmeters, various methods of biologic standardization. Fortunately, dermatologists can obtain and learn to use, without spending too much time and money, instruments that will indicate dosage measurements far more accurately than by skin effects. The intelligent operation of a modern portable ionization dosimeter and specially measured filters may be used to determine not only the quantity but the quality of *x*-ray output. Reliance on dosage, therefore, need not be placed solely upon the word of the manufacturers or the use of constants (kilovoltage, milliamperage, etc.), or upon skin effects. However, the authors advise that dosimeter readings be compared with skin effects—one method acts as a check against the other. The skin effects may serve to detect defects in the dosimeter and *vice versa*.

The technic used by American dermatologists has been employed by them for many years. It has been found very satisfactory and has stood the test of time. It is, of course, being constantly improved as will be demonstrated if the reader will compare this edition with the first edition. Unexpected, severe, acute reactions are now rare in American dermatology. Sequelæ such as telangiectasia, atrophy, sclerosis, keratosis, etc., without severe antecedent reactions, are still too common. At times these are caused by accidents and technical errors, but more often they are the result of faulty judgment. It requires a comparatively short time to master the technic, but many years are needed for experience and judgment and in some instances the latter attribute is never attained.

The requirements of superficial roentgen therapy, while having much in common with deep therapy, are, nevertheless, much less exacting from a technical standpoint. The vast majority of dermatoses amenable to roentgen therapy will yield to a few very small, widely spaced doses, if they will respond favorably at all. It is seldom necessary to evoke erythema except when treating diseases such as malignant neoplasms. In dermatology it is not necessary to jeopardize the health of the skin and subcutaneous tissues by attempting to administer large doses to a depth of several or many centimeters. There may come a time when the dermatologist will use more filtered radiation; or he may employ more grenz rays. However, such is not the case at present and it is not profitable in this chapter to speculate

on ultimate possibilities. During the past decade the tendency has been to use lower voltages. Many dermatoses yield to 60 kv. radiations as well as to 100 kv. radiations.

Superficial roentgen therapy has been in the hands of dermatologists for a very long time. It should and it will undoubtedly continue to be an essential part of the specialty of dermatology. Technical perfection is essential, but much more is required in order to obtain good results and avoid bad ones. It is necessary to be an expert dermatologic diagnostician and therapeutist. It is very important to know what dermatoses are amenable to x-ray therapy, what size doses to administer, how many such treatments can be given with safety, how often they should be given, what results to expect, whether to use x-rays alone or combine them with topical agents, diet, hygiene, internal remedies, etc. The operator should be acquainted with all possible bad results, how they are caused and how they may be avoided. Knowledge of this kind is scattered through the remaining chapters of this book. The beginner should be guided by such information until he has acquired sufficient experience for the development of ideas of his own.

The average American dermatologist, and especially the beginner, is urged to employ the technic outlined in this and the preceding chapter. The senior author and those who have been associated with him have treated many thousands of cases of tinea capitis without a single instance of permanent alopecia, although much of this work was done by technicians and graduate medical students under supervision. Many thousands of treatments have been given in our office and clinic each year, and during the past thirty years there has not been an unexpected, severe, acute reaction. Also, over 700 physicians have been trained in dermatology and superficial roentgenology under the supervision of the senior author. These dermatologists, now scattered throughout the United States and in other countries, have adhered to the technic in question and have avoided bad results. Surely this is enough evidence to establish the reliability of the technic for practical dermatologic purpose and to refute the personal equation allegation. There have been a few cases of sequelæ, but few of them have been caused by technical errors. For the most part they have been the result of poor judgment and carelessness on the part of men who were incapable of guidance.

Specifically, the beginner is advised to depend on combined technic, i. e., estimation of intensity and quality by means of ionization, utilization of constants (kilovoltage, milliamperage, distance and time factors) and checking by skin effects. If possible the voltmeter calibration and the ionization estimations should be done by a physicist. If necessary, the operator may calibrate and standardize his own apparatus and instruments. He should not make a single step unless he is sure of himself. He should carefully digest the practical chapters

in this book. This is not egotism; it is an endeavor to prevent trouble for the beginner. It is a good plan to have an ionization dosimeter but do not depend upon it to the exclusion of checking and standardization by skin effects. One can have a lot of fun and gain much knowledge by possessing and experimenting with various instruments of precision, and the technic may, in this way, be made more accurate. Such instruments are expensive but not so much as they were formerly.

Regardless of technical perfection, skill, experience and knowledge, there are two words that should be iterated and reiterated, words that should be always in the mind of the operator, namely, *extreme caution* The operator should realize that the most precise technic used in practice today is scientifically inaccurate, and that even an absolutely perfect technic will not eliminate the possibility of bad results It is, therefore, necessary to be very cautious. Plan and think before a treatment is given, not after the treatment has been given

Records.—For medico-legal reasons, as an office record, and for the purpose of statistics, it is important to preserve a record of each case Every dermatologist will compile a history card and index system best suited to his individual requirements. Instead of a card the authors prefer a sheet of fairly heavy paper folded so as to make four pages. The dimensions, after folding, are $8\frac{1}{2}$ x 11 inches. This is kept in a manila envelope and filed in an ordinary letter file. The first page deals with the history of the patient, while the three remaining pages record the treatments and observations The first and second pages of such a chart are herewith appended:

First Page

Name Mr Paul Nezzer.

Address 1492 Madison Avenue, New York City

Referred by Dr Louis Norman, 212 Zero St, New York City.

Date September 7, 1914 *Age* 56 *Mar* *Sing* *Wid*

Occupation Broker *Nationality* U S A *Blond* *Brunette*

Duration of present eruption 6 years *Of disease* 6 years

Size Dime *Photograph No* 806

Location—Distribution Center of left cheek

Diagnosis Epithelioma (basal cell)

Family History Negative

Past History Very slow evolution Has grown more rapidly during past six months Lesion has never been treated except with mild ointments

Laboratory Findings Small piece of lesion examined in Skin and Cancer Unit, New York Post-Graduate Medical School, Columbia University, shows anatomic structure of basal-cell epithelioma Biopsy No 1220

Present Condition Lesion consists of a hard mass, elevated $\frac{1}{4}$ inch Margin is composed of semitranslucent nodules Center is crusted Crust, when removed, reveals underlying necrosis

Second Page

Date	Formula	Filter	Areas	Dose	Remarks
Sept 7 1923	$2 \times 100^2 \times 9 / 8^2$	None	Lesion and surrounding skin	900 r	Curettage under procaine skin for ½ inch outside of lesion treated
Sept 25 1923					Mild second degree reaction wet dressing of diluted aluminum acetate
Nov 7 1923	$2 \times 100 \times 6 / 8$	None	Same as before	600 r	Healing is complete reaction has disappeared no evidence of epithelioma
Jan 15 1924					Erythema after last treatment which lasted one week clinical cure
Jan 2[illegible] 1927					No return of epithelioma no sequelæ almost imperceptible scar photograph No 870

BIBLIOGRAPHY

Arntzen Leif and Krebs Carl Investigation into the Biological Effect of Filtered and Unfiltered X Rays as Measured on Peas Acta radiol 4 5 1925

Bachem Albert Principles of X Ray and Radium Dosage Chicago Bachem 1923 p 34

Behnken H Die Vereinheitlichung der Rontgenstrahlen Dosismessung und die Eichung von Dosismessern Ztschr f techn Phys 5 3 1924

Cipollaro A C Dangers Incident to the Indiscriminate Use of Radium Compounds or Radon Jour Am Med A n 115 1996 1940

Duane William The Scientific Basis of Short Wave Length Therapy Am Jour Roentgenol 9 781 1922

Glasser O Quimby E H Taylor L S and Weatherwax J L Physical Foundations of Radiology New York Paul B Hoeber 1944

Hazen Henry H and Milstead Laurence C Epilation in Mice as a Biologic Standard for Determining Roentgen Ray Dosage Arch Dermat and Syph 13 230 1926

Hoffmann Carl Strahlenharte und biologische Wirkung Strahlentherapie 43 140 1932

Kronig Bernhard und Friedrich Walter Physikalische und biologische Grundlagen der Strahlentherapie Strahlentherapie Supp 3 1918

Kronig Bernhard and Friedrich Walter The Principles of Physics and Biology of Radiation Therapy New York Rebman Company 1922

MacKee George M and Andrews George C Coolidge Tube Quantitative Variations Am Jour Roentgenol 11 555 1924

MacKee George M and Cipollaro Anthony C The Roentgen Unit in Dermatology Arch Dermat and Syph 30 761 1934

MacKee George M and Eller Joseph J Variations of Cutaneous Toleration for Roentgen Rays Jour Am Med Assn 87 1533 1926

MacKee G M Mutscheller A and Cipollaro A C The Area Factor in Roentgen Irradiation Arch Dermat and Syph 47 657 1943

Packard Charles The Quantitative Biological Effects of X Rays of Different Wave Lengths Jour Cancer Res 11 1 1927

Solomon Iser Sur la mesure de la dose profonde en radiothérapie très pénétrante Bull et mém Soc de radiol méd de France 10 30 1922

Villard P Instruments de mesure à lecture directe pour les rayons X Arch d électr méd 16 692 1908

Wood Francis C Effect on Tumors of Radiation of Different Wave Lengths Am Jour Roentgenol 12 474 1924

CHAPTER XVII

FILTERED *X*-RAY TECHNIC.

ABSORPTION.

THE word penetration is used to denote the ability of roentgen rays (and radium rays) to pass into and through material that is impervious to light It is preferable to visualize this characteristic in terms of absorption rather than penetration. In passing through matter some radiation is lost by absorption. The emerging beam is composed of secondary radiation, scattered radiation, and the remainder of the original primary beam

Absorption depends upon several factors. Rays of comparatively long wave lengths ("soft rays") are more readily absorbed than are those of short wave length ("hard rays"). Absorption, also, is roughly in proportion to the density of the material through which the radiation passes and, of course, varies with the thickness of this material

REDUCTION IN INTENSITY.

Reduction in intensity of initial radiation depends upon two factors: (1) The composite radiation spreading out from a small source decreases in intensity inversely as the square of the distance. (2) Reduction in intensity of radiation passing into or through matter is due to absorption and this depends upon the wave length of the radiation and on the density of the absorbing material. There is no loss in intensity through absorption by air for distances used in practice for the harder rays. Furthermore, there is no change in quality (wave length) by distance Ethereal waves in vacuum travel unchanged indefinitely unless obstructed by matter of sufficient density to cause absorption Therefore, distance is not a filter

The effect of wave length and density on absorption must be clearly understood For a given substance absorption will depend upon wave length. The absorption of each wave length follows an exponential law, *i e*, successive layers of like thickness of a given material will absorb the same fraction of radiation received on its proximal surface Thus, if 1 mm aluminum cuts down initial intensity 50 per cent, the second millimeter will reduce intensity to 25 per cent, the third millimeter to 12½ per cent, and so on This rule ignores loss of intensity by distance, but such loss is negligible for a few millimeters of absorbing material because the source of radiation is usually at a distance of several inches

It is important to note that the proportionate rate of absorption

for a given material in the case of rays of long wave length is very much greater than for those of short wave lengths

The radiation from every roentgen tube is heterogeneous—composed of rays of different wave lengths The wave length varies with the voltage Radiation from a tube operated at 140 kilovolts will contain rays of shorter wave length than will radiation from the same tube operated at 60 kilovolts But in either instance the composite bundle of rays is heterogeneous

When this heterogeneous radiation passes through successive layers of aluminum of equal thickness, absorption will not be exponential At low voltage most of the radiation consists of long wave lengths A very large part of such radiation will be absorbed by the first few millimeters of aluminum, very little being left for absorption by the deeper layers Conversely, with high voltage, where there are more short waves than long waves, there will be a more uniform absorption throughout many layers of aluminum Furthermore, after high voltage *x* rays have passed through about 6 mm of aluminum, the radiation approaches homogeneity but a beam of *x*-rays never really becomes homogeneous Absorption of such radiation will be approximately exponential

What has been said relative to absorption of radiation by aluminum is true for human tissue Ignoring loss of intensity by distance and the fact that human tissue varies somewhat in density, absorption for any given wave length follows an exponential law Perthes and others have found that absorption by most animal tissue was about the same as water Using water as the absorbing medium, he found that aluminum is from seven to ten times as effective an absorber of *x*-rays as is animal tissue But is pointed out by Colwell and Russ that is nearly three or four times as much as its density would suggest It would seem then that 1 mm of aluminum will absorb about the same amount of radiation as will be absorbed by about 7 mm of average animal tissue The amount of absorption in a given thickness of aluminum or tissue will depend, as we have already seen on the wave length About 50 per cent of a 100 000 volt radiation will be absorbed by 3 mm of aluminum (Hull) The percentage will be less for higher voltage and greater for lower voltage

FILTRATION

By filtration is meant the interposition of some more or less impervious material through which the rays must pass before reaching the surface to be irradiated

Choice of Filtering Material —In roentgen therapy various substances have been used for this purpose

Aluminum has been for a number of years and still is the popular filter among dermatologists There are fairly definite reasons for this popularity 1, There are no reports of radiodermatitis resulting from

the secondary radiations from aluminum even when the metal is placed in contact with the skin In this connection, Whiddington has detected a very "soft" type of secondary radiation from this metal which he considers characteristic. 2 Aluminum is light and easily handled. It can be obtained as foil in thickness of 0.1 mm Sheet aluminum ½ mm. or 1 mm. thick can be cut to match the shape and size of the diaphragm of the tube stand A number of such discs permit light or heavy filtration. The low density of the metal permits the use of greater thickness, therefore reducing the danger of error when measuring thickness or uniformity of thickness of the filter For medium and high voltage roentgen therapy copper is the filter commonly employed. For super voltage (400 to 1000 kv) therapy lead filters are employed When radium is employed the common filters are gold and platinum Brass and aluminum are employed as filters for beta ray therapy.

Object of Filtration.—Filtration has two main objects. In the first place, it cuts off soft rays In the second place, it makes a heterogeneous beam of x-rays more homogeneous thereby increasing the transmission of an x-ray beam to an optimum suitable for practical purposes. Rays emitted by a roentgen tube are filtered by the glass wall of the tube It is for this reason that there is very little radiation emitted from the ordinary roentgen-ray tube when working with voltages of 40 kv or less Nevertheless, rays emitted by a roentgen bulb are spoken of as unfiltered.

When treating thick lesions or lesions situated in subcutaneous tissues it is desirable to use an x-ray beam sufficiently hard to reach the deep-lying cells. This hardness may be obtained by increasing the voltage or by using a filter In most instances the voltage is increased and the radiation passes through a filter.

It should be clearly understood that filtered rays are not more penetrating than unfiltered rays obtained with the same voltage That is, a filter does not make a beam of x-rays harder but simply removes (absorbs) the softer rays Inasmuch as the bulk of radiation from a tube even when operated at moderately high voltage consists of "soft" rays, heavy filtration causes an enormous reduction of intensity, but this loss is compensated by increasing the exposure time or decreasing the distance

The point to be emphasized is that the filter absorbs all the soft rays which might be injurious to the skin when treating deep-seated lesions.

Thickness of Filter.—Physicists and roentgenologists have devoted considerable time to the study of filtered x-rays, and a great deal has been accomplished For deep therapy, roentgenologists usually employ 150 or more kilovolts and a filter of 0 5 to 2 mm of copper or zinc and 1 to 6 mm. of aluminum Many operators estimate the distribution of radiation within the tissues or the dose at any given depth, by means of depth-dose charts

The dermatologist ordinarily employs unfiltered x-rays. When filtered radiation is desired in cutaneous therapy, it is customary to employ from 0.5 mm. to 3 mm. aluminum. The use of a filter is a question of individual judgment based on experience and a knowledge of the literature.

When using filtered radiation most dermatologists are guided by visible skin effects as with unfiltered radiation. No more filtered radiation is given than can be tolerated by the skin.

There is a difference of opinion regarding the desirability of using a filter of aluminum (from 0.1 mm. to 1 mm.) for the treatment of superficial conditions. There may be some advantage in using a filter which will absorb rays that otherwise would be absorbed by the skin. The authors, however, are not convinced of the advantage of a thin filter in very superficial diseases. Over 1000 patients have recently been treated by us with filtered x-rays (137 kv. and 1 mm. aluminum) at the Skin and Cancer Unit, New York Post-Graduate Medical School, Columbia University, and the therapeutic results were no better than with unfiltered radiation. Filtration is not as important in roentgen therapy as in radium therapy because, with radium, beta rays should be excluded except when treating very superficial conditions. Furthermore, in radium therapy filtration to some extent offsets the disadvantage of having the source of radiation close to the skin.

Position of Filter.—It is customary to place the aluminum in the diaphragm of the tube-stand, a holder being provided for this purpose. Roughly, this position is about half way between anode and skin. For accuracy the position of the filter is of no importance. Secondary rays play an important role in filtered work but injurious secondary rays are obtained only from heavy metals. When these are used as absorbing material they should be covered with aluminum to absorb the soft secondary radiations. Some operators place the filter on the skin or very close to the skin and connect it to the ground to prevent sparking.

Wave Lengths Suitable for Filtration.—There are no special advantages to filtering x-rays of 60 kv. to 100 kv. The quality of an x-ray beam of 60 kv. filtered through 2 mm. Al may be similar to that of an unfiltered x-ray beam of 100 kv. With 60 kilovolts the amount of radiation passing through the filter will be far less than with 140 kilovolts. Increasing the voltage increases intensity as well as the quality of an x-ray beam. At high voltage there are more rays of shorter wave length than with low voltage so the quality after filtration for the two extremes would be different.

Filtration Dosage.—There is no unanimity of opinion relative to filtered dosage. Some authors aver that it is possible to give two, four, ten and many more times the erythema dose of filtered rays without injurious effects. Statements like this do not mean much unless accompanied by explicit technical details. Two minutes with

certain factors will effect an erythema with unfiltered radiation The same radiation filtered through 3 mm. of aluminum requires about twenty minutes to produce an erythema.

The increase in time is caused by two factors: (1) Reduction of intensity and (2) the excessive reduction in those wave lengths that would have been entirely absorbed in the skin.

Technic Advised by the Authors.—It is desirable to have a technic as accurate as possible. Also, it is advantageous to have dosage expressed in a universal or international unit. Work done by numerous physicists and pure roentgenologists (Friedrich and Glasser, Villard, Friedrich and Kronig, Behnken, Solomon, Meyer and Glasser, Pfahler, Duane, Bachem, and many others) in an attempt to standardize methods of dose estimation with ionization and spectrometry and the creation of an international dose unit, is of great importance.

The following method has been used by the authors to calibrate new x-ray installations. The chamber of the ionization dosimeter is placed directly below the anode in such a way as to avoid back scatter. This is accomplished by placing the chamber over the edge of a table. The roentgen measurements are therefore made in air and so expressed. The next step is to decide upon certain factors, let us say 140 kv., 5 ma., skin-anode distance of 10 inches, 3 mm of aluminum. The object is to determine the time required to obtain an erythema dose with these factors with a given x-ray tube and a given apparatus. It has been determined experimentally that with the above factors 550 roentgens are required to obtain an erythema. Therefore it is necessary to find the time required to produce 550 r. Many dosimeters have a scale that reads no more than 100 r. It is therefore necessary to determine the number of roentgens delivered per unit time. Let us say for sake of argument that in one minute 91 roentgens are emitted. Since 550 r are required to cause an erythema and since 91 goes into 550 approximately six times, the time required to produce an erythema is therefore six times one minute or six minutes This hypothetical problem is given to demonstrate the method of calculating erythema doses in terms of roentgens.

The following charts, and the technic they represent, were obtained thus: The constants were first decided upon and carefully maintained throughout the exposure. The time factor for the erythema dose was then ascertained by exposing a large number of 1-inch square areas of skin on some sensitive part of young adults. It is an average erythema dose. It may be increased for aged subjects and for tiny areas. It must be reduced for large areas and for very young subjects It must be borne in mind that these charts do not represent actual doses for any equipment. They are included here simply as illustrations so that similar charts may be made by the beginner or by a physicist for particular equipment. Charts of this type are not essential because most roentgenologists seldom vary their technic. Dose charts have

been made for various sets of factors. The distance, voltage and milliamperage are the same in every instance. The other constants vary.

Fig 64 ma 5, kv 137, distance 10 inches, filter 3 mm aluminum

Fig 65 ma 5 kv 137, distance 10 inches, filter 1 mm aluminum

Fig 66 ma 5 kv 137, distance 10 inches, filter ½ mm aluminum

It is a good plan for the operator to make copies of the charts and place them on or near the switchboard. The operator must be certain of his constants (milliamperage, voltage, distance, time and filter) throughout the entire exposure. Only aluminum can be used.

Special types of filtered technics have been described and used by roentgenologists. An elementary knowledge of these is essential. We shall describe here the Coutard, the Chaoul and Heublein technics.

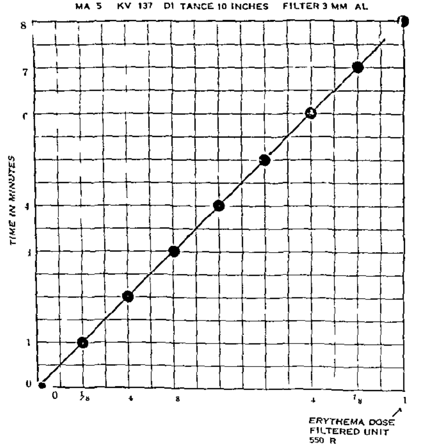


FIG 64 —Dose chart for filtered x rays. This is correct for any equipment provided that the factors mentioned yield 550 r.

COUTARD TECHNIC

The protracted fractional method of irradiation conceived at first by Regaud, improved by Kingery and later by Pfahler, and finally developed by Coutard, has many advocates and is constantly gaining in popularity *here and abroad*. Modifications of Coutard's technic have been used by dermatologists.

The work of Regaud is well known. He called attention to the fact that if a given quantity of radiation is administered at a slow rate, the tissues will tolerate a larger total dose. This forms the basis of Coutard's technic. It differs from other methods of administering radiation in that a certain dose is given in a much longer period of time and that the total dose is greater than has been administered heretofore

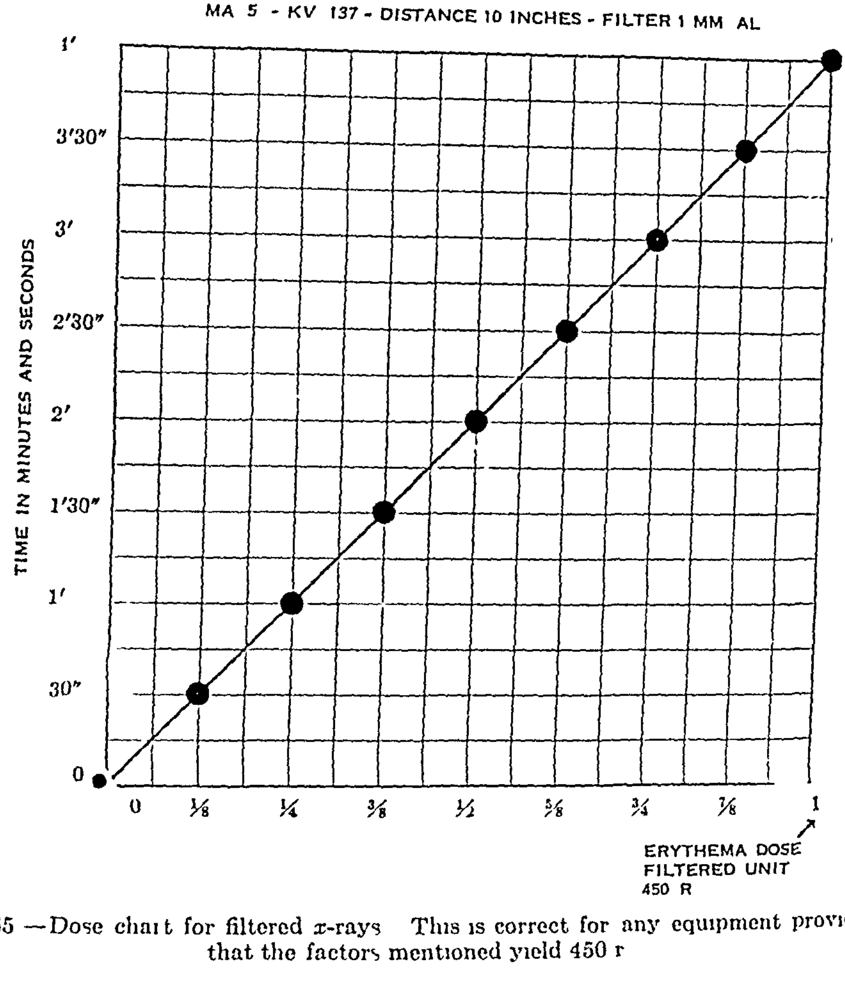


FIG 65 —Dose chart for filtered *x*-rays This is correct for any equipment provided that the factors mentioned yield 450 r

The reaction following Coutard's technic is severe, producing a second degree radiodermatitis to which the term radio-epidermitis was given by Regaud and Nogier This reaction appears on the twenty-sixth to the twenty-eighth day after the beginning of the treatment A similar type of reaction affects the mucous membranes about the fourteenth day. This is the so-called radio-epithelitis of Coutard According to the originator of this technic, these reactions are essential because when they do not occur, the neoplasm recurs More severe reactions which have followed this method are bone necrosis, muscular atrophy and paralysis, necrosis of the cartilage, cutaneous atrophy, scleroderma, and edema of the glottis.

Coutard employs high voltage (170 kv), low milliamperage (4 ma), skin anode distance of 50 cm, large fields (50 sq cm), and heavy filtration (2 mm zinc). The average duration of each treatment is fifty minutes. A low intensity of about 3 or 4 r per minute is employed. A dose of about 200 to 900 r per day is administered. The total dose measured on the skin varies from 5,000 r in seventeen days to 13 000 r in fifty days.

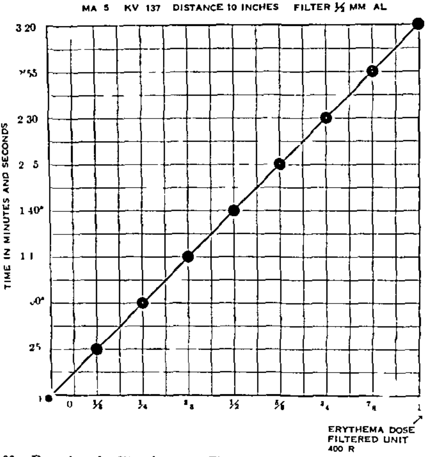


FIG 66 —Dose chart for filtered x rays. This is correct for any equipment provided that the factors mentioned yield 400 r.

Such large doses with such severe reactions are rarely required in the treatment of cutaneous neoplasms.

CHAOUL'S TECHNIC

Professor Chaoul acknowledging superiority of radium over x-rays in the treatment of cancer devised the close-roentgen irradiation technic.

A specially constructed tube and stand are required. The tube has to be completely shielded so that it is both x-ray and shock proof. The tube is so constructed that the grounded anode may come in direct

contact with the lesion About 4 milliamperes of current are used and 50 to 60 kilovolts. The x-rays emitted from this tube have an inherent filtration equivalent to about 2 mm. of aluminum. This radiation is practically all absorbed by about 4 cm. of tissue. The treatments are given daily over a period of several weeks until a total dose of about 10,000 r is administered

This method has the advantage of confining the radiation to the pathologic tissue, it acts as a cauterant; practically all the radiation is absorbed by the neoplastic tissue; the x-ray beam is softer than any used heretofore (exclusive of grenz rays). The method has not been sufficiently used in dermatology to determine its superiority over the present method of dermatologic roentgentherapy

Chaoul reported on the treatment of 281 cancer patients with the following results: Skin carcinoma, 93 per cent cured, cancer of the lip, 83 per cent cured, cancer in the oral cavity, 40 per cent cured. He also observed recoveries in cases of melanoma

Some have used this form of radiation for the treatment of skin diseases other than neoplasms. The reports are encouraging The main advantages claimed for contact therapy are that the shorter skin-anode distance makes it possible to deliver a large dose of x-rays in a short time, and also that intra-oral lesions can be reached more easily and more certainly. These advantages are practically overcome by modern shockproof apparatus It is well to consider the Chaoul method of irradiation (contact therapy) as therapy with low voltage (50 to 60 kv.) lightly filtered x-rays, with no particular advantages over x-rays of the same quality and approximately the same intensity, emitted from ordinary shockproof apparatus

HEUBLEIN'S TECHNIC.

So far as we know the method of total irradiation of the entire body is carried out mostly at the Memorial Hospital, New York City. The results with this method are not particularly encouraging It is suggested, however, that it may be used to advantage in the treatment of certain generalized dermatoses, such as leukemia cutis, mycosis fungoides, etc.

The following description of the Heublein unit is taken from an article by Craver and MacComb "The unit consists of a ward containing four beds, and having an x-ray tube operating at 186 kv and 3 ma, mounted near the ceiling behind one wall, so that two beds are 5 4 meters, the other two beds 7.3 meters from the tube The filtration is now 2 mm of copper The intensity of the radiation reaching the near bed is 1 7 r per hour, that reaching the far bed is 0 9 r per hour. Taking 750 r as the skin erythema dose for a single exposure to ordinary high voltage x-rays, the time required to deliver 30 per cent of this dose, or 225 r, to a patient in the far bed of the Heublein unit is two hundred and fifty hours." The total dose used was from 5 to 50 per

cent of the erythema dose One case of mycosis fungoides was treated in which an excellent result was observed

OMISSION OF FILTER

We know of many instances where operators administered a heavy dose supposedly of filtered radiation, but found that they had failed to insert the filter Naturally, the result of such an error is likely to be serious There are mechanical devices on the market for the purpose of preventing such an accident The operator should make it a rule to see that the proper filter is in position before treatment is begun It should be the last thing that is done before beginning the exposure It is not safe to trust one's memory or even a mechanical device The possibility of this error should be always in mind A good rule to follow both for medicolegal protection and also as a reminder that the filter has been properly inserted, is to have someone actually observe its insertion and have the initials of the checker placed on the chart

ARITHMETICAL COMPUTATION

The roentgen values selected for erythema doses using filtered and unfiltered radiation have been arbitrarily selected and represent averages from tests performed on many hundreds of test areas The erythema dose for unfiltered radiation with 100 kilovolts is 300 roentgens The erythema dose for filtered radiation using 137 kilovolts and with $\frac{1}{2}$ mm aluminum is 400 r, with 1 mm aluminum is 450 r, and with 3 mm aluminum is 550 r

The filtered erythema dose, or filtered unit, for any given set of constants may be ascertained by visible skin effects and its r equivalent which may be obtained with an ionization dosimeter Any constant, except the filter, may be changed and the dose calculated arithmetically

We tested many types of x-ray installations both shockproof and non shockproof on many hundreds of skin areas in order to determine the number of roentgens required to produce erythema Aluminum filters of 0 5 1 and 3 mm were used To illustrate the workings of arithmetical computations for filtered x-rays we selected one apparatus which gave an erythema and measured 550 r whenever the same electrical factors were used and the radiation was filtered through 3 mm Al It was found that fewer roentgens were required to produce an erythema with 1 mm Al, and still fewer when 0 5 mm Al filter was used The electrical factors are represented in the following formulas It must be emphasized that these electric constants hold true for just one apparatus Each machine differs and so each x-ray installation has to be calibrated Physical calibrations can be completed in one afternoon whereas biologic calibrations require several weeks

For 3 mm. Aluminum.

$$\frac{\text{Ma } 5 \times \text{Kv } 137^2 \times \text{T } 8'}{\text{D } 10^2} = \text{erythema dose} = 1 \text{ unit} = 550 \text{ r}$$

For 1 mm. Aluminum.

$$\frac{\text{Ma } 5 \times \text{Kv } 137^2 \times \text{T } 4'}{\text{D } 10^2} = \text{erythema dose} = 1 \text{ unit} = 450 \text{ r}$$

For $\frac{1}{2}$ mm. Aluminum.

$$\frac{\text{Ma } 5 \times \text{Kv } 137^2 \times \text{T } 3'\,20''}{\text{D. } 10^2} = \text{erythema dose} = 1 \text{ unit} = 400 \text{ r}$$

It will be noticed that an erythema formula must be established for each thickness of filter used. The electric factors may be changed and arithmetical computations may be made as demonstrated in Chapter XVII. The method is subject to gross error, but it is of service when it is desired to obtain the approximate result with any set of constants. The ionization method of determining *x*-ray output with any set of constants is both practical and accurate. The variations from the true readings are plus or minus 5 per cent.

When using the terms filtered skin unit and filtered erythema dose, it is necessary, of course, to mention the thickness of the filter, and it is advisable also, to give all the constants employed, including the roentgen output measured in air. The erythema dose for filtered *x*-rays is not the same as the epilating dose. The epilating dose remains at 300 r regardless of whether the radiation is filtered or unfiltered (see article by MacKee and Cipollaro).

ESTIMATION OF DOSAGE BELOW THE SURFACE.

One fault with all forms of measurement of intensity in roentgen therapy, is that intensity is estimated at the surface of the part irradiated. There is no generally accepted method of estimating intensity at a given depth in cutaneous roentgen therapy Such estimations are approximate In attempting approximate estimations of intensity at a given depth there are two facts that must be kept in mind: (1) Loss of intensity by distance and (2) loss of intensity by absorption The depth dose is also affected by the filtration, the anode-skin distance, and size of the irradiated field Figures for loss of intensity by absorption will be found in Chapter XII In this connection Guilleminot, years ago, prepared a table to show the (approximate) rate of absorption for different thicknesses of human tissue with filtered and unfiltered roentgen rays (Table 18) Eliminating loss of intensity by absorption, the loss by distance will be inversely as the square of the distance Many attempts have been made to estimate depth intensity by a combination of ionization dosimeter, spectrometer, water-phantom, and in other ways, hence the depth-dose charts of Dessauer, Duane, Pfahler, Glasser, and others. These charts have been used

for deep therapy Isodose curve charts are available for approximating the depth dose at different levels below the surface for every combination of conditions (see Chapter XII) A series of experiments were conducted by Cipollaro and Mutscheller in order to determine the quantity of x-rays absorbed by successive millimeters of skin Radiations usually employed in dermatology were selected for this study In this connection it is necessary to mention the *exit dose* It is the dose of x rays which is transmitted through small thickness of tissue such as the hand If a full skin tolerance dose is applied to the palmar and dorsal surfaces of the hand with a beam of x rays sufficiently hard to penetrate the thickness of the hand, then the exit dose added to the skin tolerance dose would be sufficient to cause radiodermatitis Andrews, Braestrup and Heisel have recently discussed this phase of radiology

Increasing the distance of the source of radiation tends to equalize intensity throughout a given depth At great distance the amount of radiation received at a given depth in relation to the amount received at the surface is greater than at short distance This is due to the fact that with the source of radiation at a distance the rays are more perpendicular and therefore they are not lost by spreading out obliquely (in a fan-shaped manner) as they pass through the tissue

TABLE 18 —DEPTH OF TISSUE PENETRATED BY X-RAYS (GUILLEMINOT)

Quality of rays	Surface.		Depth of tissue								
			0.5 cm.	1 cm	2 cm	3 cm	4 cm	5 cm	6 cm	7 cm	8 cm
4 Benoist	Dose transmitted	100	65	43	22	13	8	5 2	3 8	2 6	1 8
5		100	72	53	32 5	21 9	15 5	11 6	8 8	7 0	5 6
6		100	8	63	44	33	26	12	17 2	14 4	12 0
7		100	81	68	50	39	32	26 5	25 8	19 7	17 2
8		100	83 2	69 9	52 7	42	34 8	29 5	22	22 3	19 5
Filter											
8 1 mm		100	86 5	6 2	61 1	50 0	43	3 3	32 6	28	25 2
8 2 mm		100	89 2	80 4	67	57 1	49 4	43 3	38 2	33 8	30 1
8 3 mm		100	91	83 5	71 8	61 8	51 5	48 0	42 5	3 8	34 8
8 4 mm		100	92 8	86	4 5	65 4	57 8	51 3	45 7	41 0	37 0
8 5 mm		100	95	87	76 1	67 2	60	53 8	48 5	44 0	40 4

Another way in which intensity can be increased in the deeper tissue is by cross fire A discussion of cross-fire methods will be found in the Chapter on General Therapeutic Considerations

BIBLIOGRAPHY

ANDREWS G C BRAESTRUP C B and HEISEL E B Exit Dose in Dermatologic Roentgen Therapy Arch Dermat and Syph 50 355 1944

BACHEM ALBERT Principles of X Ray and Radium Dosage Chicago Bachem 1923

BARKLA C G and SADLER C A The Absorption of Rontgen Rays Phil Mag 17 739 1909

BEHNKEN H Die Vereinheitlichung der Rontgenstrahlen Dosismessung und die Eichung von Dosismessern Ztschr f techn Phys 5 3 1924

Chaoul, H.: Weiterer Beitrag zur Röntgennahbestrahlung des Karzinoms, Strahlentherapie, 50, 446, 1934.

Cipollaro, A. C., and Mutscheller, A.: Absorption of Roentgen Rays by the Skin, Arch. Dermat. and Syph., 41, 87, 1940.

——— Roentgen Dosage in Dermatology Expressed in International Roentgens, Arch. Dermat. and Syph., 41, 1, 1940.

Close Roentgen Irradiation as Substitute for Radium Therapy, Jour. Am. Med. Assn., 107, 1823, 1936 (Berlin letter.)

Colwell, Hector A., and Russ, Sidney: Radium, X-rays and the Living Cell, London, Bell, 1915, pp. 20-23.

Coutard, Henri: Roentgen Therapy of Epitheliomas of the Tonsillar Region, Hypopharynx and Larynx from 1920 to 1926, Am. Jour. Roentgenol., 28, 313, 1932.

Craver, Lloyd F., and MacComb, William S.: Irradiation of the Entire Body (Heublein Method), New York State Jour. Med., 34, 249, 1934.

Dessauer, F., und Vierheller, F.: Die Tiefenwirkung der Röntgenstrahlen, Strahlentherapie, 12, 655, 1921.

Duane, William: Roentgen Rays of Short Wave-lengths and Their Measurement, Am. Jour. Roentgenol., 9, 167, 1922.

——— Measurement of Roentgen Radiation by Means of an Ionization Chamber and Galvanometer, Am. Jour. Roentgenol., 9, 467, 1922.

Fricke, Hugo, and Glasser, Otto: Studies on the Physical Foundations of Roentgen-ray Therapy, Am. Jour. Roentgenol., 11, 435, 1924.

Friedrich, W., und Glasser, O.: Untersuchungen und Betrachtungen über das Problem der Dosimetrie, Strahlentherapie, 14, 362, 1922-1923.

Gaylord, Harvey R., and Stenstroem, K. Wilhelm: Comparative Measurements between Radium and X-rays Concerning Energy Absorbed at Depth, Am. Jour. Roentgenol., 10, 56, 1923.

Guilleminot, H.: Sur la loi d'action biologique des rayons X filtrés et non filtrés, Compt. rend. Acad. d. sc., 156, 1943, 1913; Abstr. Arch. d'électric. méd., 22, 331, 1914.

Krönig, Bernhard, und Friedrich, Walter: Physikalische und biologische Grundlagen der Strahlentherapie, Strahlentherapie, Supp. 3, 1918.

MacKee, George M., and Cipollaro, Anthony C.: The Roentgen Unit in Dermatology, Arch. Dermat. and Syph., 30, 761, 1934.

MacKee, G. M., Cipollaro, A. C., and Mutscheller, A.: Shock-proof Roentgen Ray Apparatus in Dermatology, Arch. Dermat. and Syph., 47, 43, 1943.

Meyer, William H., and Glasser, Otto: Erythema Doses in Absolute Units, Radiology, 6, 320, 1926.

Perthes, G.: Versuch einer Bestimmung der Durchlässigkeit menschlicher Gewebe für Röntgenstrahlen, Fortschr. a. d. Geb. d. Röntgenstrahlen, 8, 12, 1904.

Pfahler, George E.: The Treatment of Metastatic Carcinoma of the Spine by Deep Roentgentherapy, Surg., Gynec. and Obst., 29, 236, 1919.

——— Clinical Results from the Newer Technique of Deep Roentgentherapy in Malignant Diseases, Am. Jour. Roentgenol., 8, 236, 1921.

Pfahler, George E., and Widmann, Bernard P.: Measurements on Two American and Two German Deep Therapy Machines by Means of the Duane Method and the Friedrich Iontoquantimeter, Am. Jour. Roentgenol., 11, 267, 1924.

Report from the International X-ray Unit Committee, Am. Jour. Roentgenol., 20, 470, 1928.

Russ, S.: The Clinical Significance of X-ray and Radium Measurements, Jour. Roentgen. Soc., 8, 35, 1912.

Solomon, Iser: Sur la mesure de la dose profonde en radiothérapie très pénétrante, Bull. et mém. Soc. de radiol. méd. de France, 10, 30, 1922.

CHAPTER XVIII

ROENTGEN THERAPY WITH EXTREMELY LONG WAVE LENGTHS *

Historical.—During the past thirty or thirty-five years several attempts have been made to utilize extremely long wave-length x rays for therapeutic purposes. Schultz about 1910 employed x rays produced with voltage represented by a spark gap of 1.5 cm. To this radiation he gave the name "over-soft" x rays. He was able to cure with the over-soft x-rays some cases of basal cell epithelioma that had failed to respond favorably to longer wave lengths. He claimed to have obtained some satisfactory results in cases of nevus flammeus, chronic ulcers, and other dermatoses.

It was noticed that the cutaneous reaction subsequent to a large dose of over soft radiation exhibited features that differed from the reaction caused by ordinary x rays. The objective symptoms suggested a third degree reaction—erythema, edema, vesiculation, exudation, crusting, ulceration, etc. The pain, however, was much less, the latent period was shorter, healing was comparatively rapid and sequelæ occurred with much less frequency.

Schultz employed an ordinary x ray tube which, however, had exceptionally thin glass opposite the anode. Only an occasional tube of this type would permit the passage of the over soft radiation. In fact it was so difficult to obtain a tube that would emit waves of the desired length that the method failed to become popular.

About the same time S. Stern of New York, working independently, succeeded in producing and therapeutically using very long wave lengths. The radiation employed by Stern was of about the same type as that advocated by Schultz. Soft effects were obtained, also, with the Cornell tube (Geyser) by using low voltage and placing the window of the tube in contact with the skin while in operation.

In 1888 Schott produced glass composed of silico borate of soda and aluminum which had a low atomic weight and which, therefore, transmitted x rays of very long wave lengths. Schott's glass, however, was not used for this purpose. Phillips in 1906 also succeeded in making glass that would permit the passage of very soft radiation. It was composed of silicate of soda and borax with a little lead.

* Part of the material used in this chapter was published by Francis Carter Wood and MacKee in the *Journal of the American Medical Association* 96 111 1931. For the use of this material here the authors are indebted to the American Medical Association.

As stated by Kaye, Schott had investigated the absorption of x-rays by various oxides and carbonates. The list reads, in order of diminishing "transparency": Li, B, Na, Mg, Al, Si, K, Cu, Mn, As, Ba, and Pb, a sequence which is that of atomic weight. In 1911, Lindemann constructed an x-ray tube with a window of glass made of lithium borate. This glass permits the passage of x-rays of wave lengths that would be absorbed by any other glass thus far invented The lithium borate glass, known as Lindemann glass, is not very permanent The glass was improved by Cossor who made a lithium glass that can be worked to better advantage and that permits joints to be made with platinum, as well as with ordinary soda glass and other forms of glass Cossor made an x-ray tube composed entirely of this glass. Gabriel states that Schultz and Krause both used Lindemann glass windows and that Zehden, who also experimented with long wave lengths, employed very thin soda glass.

Bucky has written numerous articles on the subject, the first of which was published in 1925. He employed a Muller tube which is specially constructed for the purpose of long wave length therapy. It is said to have an anode of low atomic weight (chromium iron) and it has a thin Lindemann glass window.

Previous workers were compelled to use induction coils, gas tubes and less accurate instruments of precision than are obtainable today Bucky has enjoyed the advantage of a hot cathode tube, an interrupterless transformer, voltmeter, iontoquantimeter, spectrograph and other modern apparatus and instruments, in addition to knowledge that has been handed down by earlier investigators in the same field It is difficult to estimate the voltage used by the earlier workers Bucky avers it was about 15 or 20 kv. His work has been done with voltage that has dropped gradually from the higher figures to a maximum of 10 kv.

Recently, x-ray tubes for intraoral use have been perfected. They provide intense radiation of long wave length There has as yet been no personal experience with this method

Physics.—It has long been known that the commercial x-ray tube emits practically no x-rays when run at a voltage of 10 kv or less The reason for this is that the glass of which the tubes are made has a high absorptive power for the long wave-length x-rays If 10 kv. is taken as the limiting value for the voltage, the shortest wave length of the x-rays which are excited is given by the well-known Duane formula, which is: The shortest wave length in Ångstrom units equals 12 35 divided by the peak voltage in kilovolts This value is obviously 1.235 Å Longer wave lengths than this are retained by the glass

Many years ago Lindemann showed that if a lithium borate glass was used, and the thickness kept low, x-rays of considerably longer wave length would escape from the tube than with ordinary glass. As the lithium glass is difficult to handle, it is usual to make the tube of ordinary glass and insert a small window of lithium glass opposite

the anticathode The construction of such tubes does not vary in principle from that of ordinary tubes The anticathode is made of tungsten or an iron-chromium alloy and the electron stream is derived from a hot cathode as in the usual Coolidge construction Water cooling of the anticathode is usual, as it greatly increases the tube output Under these circumstances, radiation from 1 to 3 Å appears in quantity outside the *x*-ray tube, though probably at least 50 per cent is absorbed even in the lithium glass window The lithium glass is not absolutely essential If the wall of the tube is kept thin enough such long wave length *x*-rays as mentioned will penetrate in large quantities, but tubes with thin glass windows are difficult to handle from the mechanical aspect X-rays of the longer wave lengths are rapidly absorbed in the air Of those of 2 Å, 20 per cent is absorbed in a 10 cm thickness of air, the corresponding absorption for 3 Å being 40 per cent It is necessary, therefore, in practice, to make accurate measurements of the skin focus distance, and it may even be advisable to filter the radiation with very thin aluminum foil, properly supported, in order to get a little more homogeneous radiation It is obvious that if 20 per cent of the shorter wave lengths is absorbed in 10 cm of air the absorption in the skin will be much higher As a matter of fact, the radiation of 3 Å loses one-half its value in penetrating at a maximum 0 2 mm of the skin, while that of 2 Å loses one half its value at approximately 1 mm below the skin surface This does not mean that a certain amount of the shorter wave lengths will not have a considerable range, and this is shown by the fact that it is possible to take excellent pictures of the bones of the hand with such radiation Also the grain structure of a piece of pine wood 2 5 cm thick is well brought out by a short exposure with such a tube, giving much more detail than is ordinarily obtained with higher voltages

The clinical measurement of these long rays can be carried out by a specially constructed ionization chamber of the thimble type The chief point is that the walls of the chamber be thin enough so that the radiation is not largely absorbed before it reaches the air of the chamber In well-equipped laboratories the measurements can be made of course, with an open ionization chamber such as is used as a standard in determining the roentgen

Biologic Effects —As the action of these supersoft ' infraroentgen, ' or grenz rays, as Bucky has called them, is wholly atomic despite their long wave lengths, it would be expected that they would follow the quantitative laws already established for the biologic action of radiation by Wood and Packard In fact, Packard has shown with the eggs of Drosophila that the biologic action of the soft *x*-rays of the type under consideration is the same as *x* rays of short wave length or gamma rays of radium the lethal curves superimposing exactly Clinically, however, the biologic effect may be expected to be somewhat different from that of shorter wave lengths, owing to the fact that the absorption takes place largely in the first few millimeters of

the skin. Consonant with this fact, the histologic changes produced have been described as slightly different from those following radiation of the shorter wave lengths, the lesions being somewhat less marked in the vessels and characterized chiefly by proliferation of the connective tissue and certain changes in the stratum granulosum of the epidermis. But it is doubtful whether there exists any fundamental difference between the reactions following the application of any wave length of x-rays to the skin.

Apparatus.—The exciting apparatus may be a stepdown transformer, the current for which is obtained from a modern interrupterless x-ray transformer, or, as is usually the case, a special transformer, designed to supply a maximum of 10 kv. and 10 milliamperes, is employed. The principle of such a transformer does not differ from that of generators used for short wave x-rays. It is simply a high tension transformer with a closed iron core. The high tension transformer is regulated by both autotransformer and resistance control. One of the high tension lines is grounded. There is a small stepdown transformer to supply suitable current for the Coolidge filament. A voltmeter and milliamperemeter are built into the switchboard. The unit is self rectified. The transformer, with its accessories, is housed in a small cabinet on which is mounted the switchboard, controls, tube stand, and the water-cooling device for the tube if the tube is water-cooled. The apparatus is designed for use with commercial 110 volt alternating current. If only direct current is available, a small rotary converter may be installed in the cabinet.

Tube.—The special tube that is most popular for the purpose is a small, water-cooled, unipolar, hot cathode glass tube which, with the exception of the Lindemann glass window, is encased in a metal housing. The tube is delicate, its life is likely to be short. It is important not to touch the Lindemann glass window. Some grenz-ray tubes now in use are air-cooled and made of pyrex glass. The window is inverted or sucked in and is made of extremely thin glass (0.001 to 0.003 in.).

Bucky and Glasser estimate the wave lengths obtained with this tube and apparatus operating on about 8 kv. as ranging from 1.6 to 2.06 Å. The average is about 2 Å. Ultraviolet rays have wave lengths between 4000 and 15 Å. X-ray wave lengths range from about 15 Å to about 0.06 Å. X-ray wave lengths commonly used in radiotherapy are between 0.3 and 0.06 Å. The grenz rays, therefore, fall well within the x-ray spectrum, but their average length is greater than that previously used for therapeutic purposes. Bucky estimates the longest x-ray wave lengths heretofore employed therapeutically at about 1 Å average.

Cutaneous Reactions.—Because of the knowledge of the biologic action of x-rays of various wave lengths, radium, and ultraviolet rays, and particularly the beta rays of low velocity, cathode rays and very soft secondary rays from heavy metals, the biologic effect of grenz

rays is exactly what would be expected Depending on the size of the dose cutaneous reactions vary from simple erythema (redness) to vesiculation and erosion, with exudation and crusting Because most of the radiation (assuming that it has an average wave length of 2 A) is absorbed by the epidermis and upper layers of the derma (depending considerably on the thickness of the skin, which varies markedly with location and disease), the deep derma and subcutaneous tissues are not likely to be seriously damaged with amounts usually employed for therapeutic purposes Therefore no deep, indolent, painful ulcers that are so characteristic of third-degree roentgen and radium reactions have yet been reported While delayed reactions occur, it is customary for the erythema to appear within twenty-four hours Regardless of the intensity of the reaction inflammation usually disappears in a few weeks deep pigmentation, however, often endures for many months Several times the erythema dose may be given at one sitting without effecting epilation although if the dose is sufficiently large epilation occurs Four, and even eight times the erythema dose of short wave length x-rays have been administered to small areas without provoking more than a mild second-degree reaction The grenz-ray erythema dose has been increased considerably more than this without effecting more than an intense erythema superficial edema, and pigmentation, with at times, vesiculation erosion exudation and crusting

Sequelæ thus far have been uncommon Cases of atrophy and telangiectasia have been reported Sufficient time has not yet elapsed and too few patients have been treated, to allow one to estimate accurately the possibility of sequelæ or to determine the possible danger of small and large doses repeated over a considerable period However, it can be said that grenz ray therapy is safer than therapy with shorter wave lengths, for both deep and superficial tissues This is especially true for unskilled operators either method is safe when properly employed The safety factor in grenz-ray therapy depends principally on using a tension below 10 kv preferably about 7 or 8 kv

Technic — As with short wave-length x rays grenz-ray dosage may be estimated by the direct method (photographic and pastille radiometers spectrometer, electrostatic voltmeter iontoquantimeter, biologically with seeds or larvæ) or by the indirect method (milliamperage voltage time, and distance) or by a combination of the two For the combined method which is the method used mostly in this country it is customary to have a physicist standardize a given apparatus and tube in terms of peak voltage wave length, roentgens and erythema dose in other words quantity and quality expressed in milliamperage voltage time, and distance An amount over 200 or 300 r (half absorption value 0 036 mm of aluminum) is likely to cause mild erythema The quantity required for the erythema dose varies considerably with different authors because as yet there is no definite clinical, biologic, or instrumental standard for the erythema

dose. Some place it as low as 200 r; others as high as 500 r or even higher. The technic should be checked frequently in the manner mentioned; also every time a new tube is used, an old tube repaired, or when any change is made in the installation. For daily use the operator depends on the four established constants, namely, milliamperage, voltage, time, and distance.

Most operators in this country utilize the combined method of estimating x-ray dosage regardless of wave length; grenz rays are included in this statement. They establish the four constants (milliamperage, voltage, time, and distance) for the erythema dose. The voltmeter is first calibrated for peak voltage by means either of a sharp-pointed or of a small sphere spark gap, preferably the latter. This is done by the manufacturer and should be checked occasionally. Eight kv., with 8 milliamperes, will give an average wave length of approximately 2 Å (half absorption value 0.036 mm. of aluminum). The working distance is 6 cm. The time factor is obtained by applying the radiation produced by the constants mentioned to small areas of skin on some fairly sensitive part, such as the flexor surface of the forearm of a young adult, in increasing amounts until erythema is evoked. The time is then recorded and added to the other constants. This is called (arbitrarily) the skin unit or erythema dose. Most operators in this country employ the following constants for the erythema dose: 8 milliamperes, 8 kv., four minutes at 6 cm distance. This gives approximately 370 r (Glasser). The time factor may be divided for fractional treatments and multiplied for massive dosage All other factors should remain fixed. A change in any one will necessitate a change in one or more of the others. The technic is checked frequently with an ionization dosimeter.

Roughly, most of the technical rules relating to shorter wave-length x-rays pertain to grenz-ray therapy; variations in skin tolerance due to age, sex, complexion, location, thickness of skin and its various layers, especially the horny layer; disease; idiosyncrasy, impossibility of obtaining an erythema color standard or index; increase of erythema or other visible biologic effect not proportional with increase of quantity or quality of radiation; possible accumulative action of repeated applications, avoidance of extremely large doses, at least until more is known relative to the possibility of undesirable late results. There are exceptions: Grenz rays produce less scattering and fewer secondary rays than do shorter wave lengths; therefore there is less difference in detectable effect when the radiation is applied to large areas as compared to small areas. Because these long wave lengths are absorbed by air, it is necessary to place the tube close to the skin; also distance must be accurately measured and maintained because the percentage of error at a short distance is considerably greater than at the working distance of 8 or 10 inches ordinarily employed with shorter wave lengths. It is advisable to shield the skin immediately around the treated area with thin lead foil. Radiation

an appreciable amount passes through only the Lindemann glass window it does not travel far and it does not excite much secondary and scattered radiation, therefore it is unnecessary to protect especially the patient's body or the operator

Therapeutic Results.—While the radiation is a useful therapeutic agent, it is less efficacious, less versatile, and more time consuming than x-rays of shorter wave length In spite of the higher degree of safety, the method is not yet suitable for use by any but those who have been adequately trained in x-ray work

The best field for grenz ray therapy is in dermatology Here the results have been good in some diseases It is especially suitable when it is necessary to avoid temporary or permanent injury to important organs and to glandular apparatus in or under the true skin—hair roots sebaceous and sweat glands, testes eyes Even here there are limitations With heavy dosage or repeated applications enough of the shorter wave lengths may be absorbed by tissue below the epidermis to effect undesirable and perhaps serious injury However the method is comparatively safe and very useful for patches of various dermatoses located on the scrotum, eyelids, and scalp—eczema psoriasis lichen planus lupus vulgaris keratoses and very superficial basal-cell epithelioma

With tubes available at present, used at a skin target distance of 6 cm, the exposed area of skin is a circle having a diameter of about 4 cm Obviously, the method is not suitable for the irradiation of universal, generalized, or extensive eruptions

Published reports of therapeutic results are comparatively meager and they come from comparatively few workers Most of the favorable results have been obtained with large doses (erythema dose to several or many times the erythema dose—from 300 or 400 to 3000 or 4000 r administered at one time and repeated if necessary at intervals of from one to several months) There has been little experience with fractions of the erythema dose administered once weekly Thus far fractional treatment has not been especially successful In general it is doubtful whether any skin disease (not an individual case) can be cured with grenz rays that cannot be cured with x rays of shorter wave lengths or with beta rays of radium Occasionally, a patch of some inflammatory dermatosis such as eczema or psoriasis that is not favorably influenced with very conservative treatment with x rays of shorter wave length will yield to a massive dose of grenz rays, more often, shorter wave lengths succeed when grenz rays fail

Good results have been reported in some of the following conditions patches of eczema of all types patches of lichen planus and psoriasis localized essential pruritus, perleche, warts of various types lupus vulgaris Bazin's disease, tuberculosis verrucosa cutis, scrofuloderma basal cell epithelioma superficial cavernous angioma, strawberry mark port-wine mark boils Kaposi sarcoma sarcoma of various

types, dermatitis herpetiformis, paronychia, ringworm of scalp and skin, acne varioliformis, Darier's disease, mycosis fungoides, keratoses, and poikiloderma. Poor results have thus far followed the use of grenz rays in sycosis, xanthoma, acne vulgaris, keloid, dermatitis papillaris capillitii, alopecia areata, prickle-cell epithelioma and tuberculide. With few exceptions the grenz rays have not yet been tried for skin diseases other than those mentioned. The authors have used grenz rays for about fifteen years in the treatment of various dermatoses. The response of skin diseases has been so poor that this method of therapy has been practically discarded. We failed to cure or even improve in the slightest degree any one of many cases of nevus flammeus which we treated.

Several dermatologists have obtained results in lupus vulgaris that seem superior to those possible with shorter wave lengths. However, the difficulty just now is that reports of success and failure are, for the most part, based on too few cases, in many instances only 1 or 2 patients having been treated. For this reason and because greater technical knowledge is required, several years must elapse before it will be possible to give an accurate or even fair evaluation of the method. During the past few years articles on grenz-ray therapy have been published which have not been, in our opinion, any more convincing than the earlier articles. Kalz wrote an extensive article on grenz rays in which he states that he cured or improved with grenz rays cases of nevus flammeus, scleroderma, poikiloderma, acne vulgaris, keloids and many other diseases which we also have treated with grenz rays without cure or improvement in a single case

Other full articles on the use of grenz rays in dermatology have been written by Ryan and by Sagher. Dostrovsky and Sagher successfully treated with grenz rays cases of cutaneous leishmaniasis. We have had no experience in the treatment of this disease with either grenz rays or x-rays.

Judging by present knowledge, Bucky's prediction that grenz rays will replace x-rays of shorter wave length in dermatology is too optimistic. It is our understanding that American dermatologists use grenz rays less today than when they were first introduced

Attempts have been made to influence various internal diseases by applying grenz rays to eight areas on the trunk. The same method (so-called general or indirect treatment in contradistinction to direct irradiation of lesions) has been used, also, for some skin diseases, especially those that involve extensive surfaces, those that are characterized by remissions and exacerbations, and those that are definitely due to some systemic disturbance. The *rationale* of indirect treatment is based on the fact that radiation of various kinds (x-rays, radium, ultraviolet rays) if properly employed will at times provoke temporary leukocytosis, also that through the autonomic nervous system such radiation may affect the endocrine glands, general nervous system, general circulation, metabolism, or vitamins. Bucky believes that

the grenz rays are more efficacious in this respect than radiation of any other wave length He gives the following technic for indirect treatment The torso is divided into four areas, front and back (eight in all) On each of eight successive days one field is irradiated at a distance of 15 cm with from 150 to 300 r When the series is completed a second series is given following the original sequence but making the exposures every second day The two series constitute a course of treatment As a rule several courses are administered with intervals of rest depending on indications

Good results for the indirect grenz ray treatment are claimed for gastric ulcer gastric hyperacidity, Banti's disease, polycythemia rubra, hypothyroidism, dysmenorrhea, oligomenorrhea, amenorrhea hypertrichosis, asthenia, arthritis deformans, asthma, pertussis, angina pectoris, and spastic constipation Exophthalmic goiter, Hodgkin's disease and leukemia are not favorably influenced The recent literature does not corroborate the earlier favorable reports published mainly by Bucky of the beneficial effects on the systemic diseases mentioned by the indirect method of grenz-ray therapy Indirect treatment was used successfully by Bucky in a number of skin diseases acne vulgaris, acne rosacea, universal erythroderma, and urticaria The effect on acne rosacea is said to be especially good

The results of indirect grenz ray treatment have not yet been corroborated to any extent also, only a few cases of each disease have been reported The method and particularly the explanation for the alleged good results have been received with skepticism It will be necessary to compile statistics from a number of clinics over a period of years before the value of indirect treatment can be ascertained As far as our personal experiences are concerned we have found the indirect method to be completely useless in the treatment of skin diseases

BIBLIOGRAPHY

Bucky G Grenz ray Therapy with contributions by Otto Glasser and Olga Becker Manheimer translated by Walter James Highman New York The Macmillan Company 1929

———— Actual Superficial Therapy by Grenz (Infra Roentgen) Rays Arch Dermat and Syph 15 672 1927

———— Grundlinien und Ausblicke der Grenzstrahlentherapie Strahlentherapie 24 524 1927 also in Fortschr a d Geb d Rontgenstrahlen (Kongressheft) 35 10 1926

———— Reine Oberflachentherapie mit uberweichen Rontgenstrahlen Munchen med Wchnschr 72 802 1925

———— Rationelle Hauttherapie durch Grenzstrahlen Jahreskur e f arztl Fortbild 17 (Heft 8) 19 1926

Bucky G and Muller E F Strahlende Energie Haut und autonomes Nervensystem Munchen med Wchnschr 72 883 1925

Dostrovsky A and Sagher F Treatment of Cutaneous Leishmaniasis (Oriental Sore) by Grenz Rays Arch Dermat and Syph 45 865 1942

Kalz F Theoretic Considerations and Clinical Use of Grenz Rays in Dermatology Arch Dermat and Syph 43 447 1941

Kaye G W C X rays 2d ed New York Longmans Green & Co 1917 p 171

Kirsch H Physikalische Untersuchungen uber die Buckyschen Grenzstrahlen München med Wchnschr 74 578 1927

Lindemann Quoted by Kaye

PHILLIPS: Quoted by Kaye.

RYAN, C: Grenz Ray Therapy in Dermatology, Brit Jour. Dermat, 54, 47, 1942.

SAGHER, F.: Therapeutic Use of Grenz (Infra-Roentgen) Rays in Dermatology, Acta Med Orient, 2, 63, 1943

SCHOTT. Quoted by Kaye.

SCHULTZ, F.: *X*-ray Treatment of Skin Diseases, New York, Rebman Company, 1912, pp 61, 81, 82, 92. Translated by James Burnet

WOOD, F. C, and MACKEE, G. M: Therapy with Long Wavelength *X*-rays (Grenz Rays). Jour. Am. Med Assn, 96, 111, 1931

CHAPTER XIX

BIOLOGIC AND BIOCHEMICAL EFFECTS OF RADIATION *

ALMOST as soon as x rays were discovered, experiments were undertaken to see how they affected living organisms Becquerel's famous radium burn, resulting from carrying a small tube of radioactive material in his pocket, drew attention to the susceptibility of the human skin to these radiations

Many of the earlier reports of radiation effects are contradictory and incomplete Records of experiments performed on only a few individuals under questionable conditions of experimental precision and without adequate controls flooded the literature However, within the last few years a great deal of painstaking work has been done with various biologic materials so that many of the *facts* regarding the effects of radiations upon them are fairly well known The *explanation* of these facts however is still far from complete

Effects on the Cell —The point of attack on any living organism must be the *cell* Changes in any cell as the result of irradiation could be produced in one of two ways—indirectly, by the action of other irradiated cells interfering with nutrition or development or directly, by the action of the radiation on the cell constituents At least some of the cells must be acted upon directly, and these are the only ones we need consider We will first describe the types of effect which may be produced, and then discuss briefly the theories which have been proposed to explain them

Except in the case of very intense irradiation, no immediate effect is observed in the cell After a longer or shorter *latent period*, changes begin to take place Canti made extensive studies and many motion pictures of the behavior of tissue cultures under various conditions of irradiation In these living cells the translucent protoplasm became turbid and then finely granular and the proteins normally in a very finely divided state formed visible aggregates The cells lost their motility and remained completely quiescent Cells which were in mitosis at the time of irradiation completed their division and then remained unchanged for some time while those not actually dividing were prevented from so doing Thus far the change was reversible If the irradiation had not been too severe the cells resumed their activity returned to a normal appearance and began to divide normally However sometimes a cell which had returned to an apparently normal condition after dividing a few times suddenly died

* In the last edition this chapter was revised by Dr Edith H Quimby Some of the material added by Dr Quimby has been retained in this edition

Even in moderately irradiated cultures, a number of cells may succumb in this fashion, but their place is eventually taken by others which have escaped injury, the final result being perfectly normal tissue

If the irradiation is sufficiently severe, the cells which are injured never regain motility, but begin to disintegrate, sometimes almost explosively.

In addition to the changes observed in living cells, others can be followed in stained preparations, particularly in the case of cells in mitosis Cytolysis occurs, the chromosomes shrink, clump together, and group themselves irregularly. The chromatin falls into fragments, the nucleus is destroyed. The protoplasm becomes more viscous, and vacuoles are formed in it. Cells in which these changes have taken place do not recover.

In addition to these specific changes in cell structure and behavior, certain physiologic reactions are affected. There is an increase in hydrogen-ion concentration, which may be very transitory in some tissues, but which in others may persist for some hours or even days

With the change in acidity is associated an increase in the permeability of the cell membranes Such a condition may allow the acid content of the cell to escape into the tissues, increasing the acidity there, and causing the increase in the viscosity of the protoplasm

In some cells respiration is decreased and glycolysis increased, but these phenomena do not always occur.

Radiosensitiveness of Cells.—Various cells differ in their radiosensitivity, so that for some types a much larger dose is necessary before changes begin. But no living organism has been found which will not be influenced if sufficient radiation is administered.

Even in cells of the same kind, maintained under constant environmental conditions, there is a wide variation in sensitiveness to radiation, some dying with a comparatively small dose, and others surviving doses several times as large. In Fig 67 are given mortality curves for several different kinds of cells, according to Packard. These curves all have the characteristic "sigmoid" form, but their slopes are quite different. Beans show mortality of some members of the group with less than 10 per cent of the lethal dose, while sarcoma 10 shows complete survival up to 30 per cent of the lethal dose

The dose of radiation required to kill one-half of the members of a group is usually studied, rather than the completely lethal dose, which may be influenced by a very few extremely resistant cells. This 50 per cent dose is indicated on the chart, for the various organisms It is seen that there is a very great difference in the relative sensitivity of the various types. To kill one-half the algæ requires 120 times the dose required to kill one-half the salamander eggs.

In 1904, Bergonié and Tribondeau announced the principle that sensitivity varies directly with the reproductive capacity of the cell, and inversely with its degree of differentiation. This was accepted very literally for a time, but is now known to be true only in a general sense Lymphocytes are highly radiosensitive, although they have a very

limited power of reproduction. On the other hand, bacteria are very resistant, although they are comparatively undifferentiated. The various cells of the human body differ greatly in radiosensitivity. Desjardins has contributed largely to our knowledge of relative radiosensitivity of various tissues both normal and diseased. In discussing the rationale of radiotherapy for inflammatory conditions he states: "it seems not unreasonable to assume that irradiation by destroying some of the infiltrating leukocytes causes the protective substances in these cells to be liberated and to be made even more readily available for defensive purposes than when they were in the intact cells. This

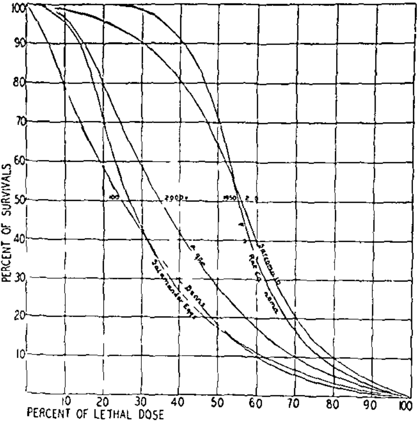


FIG 67.—Mortality curves for various kinds of cells. (Packard in Glasser's Science of Radiology, courtesy of Charles C Thomas.)

and the increase in phagocytosis which follows the disintegration of the cells represent the main effects of exposure to roentgen rays and radium." In general cells may be classified according to radiosensitivity as follows, going from greater to less sensitivity:

Lymphoid cells
Epithelial cell
Endothelial cells
Connective-tissue cells
Muscle cells
Bone cells
Nerve cells

A series of 12 articles by Warren and one each by Dunlap, Friedman and Gates appeared in volumes 34 and 35 of the *Archives of Pathology* dealing with the effects of radiation on normal tissue. The reader is referred to these articles and to the discussions of the effects of radiation on various human tissues which are found in Chapters XXI and XXII.

General Systemic Effect.—Within a few hours after the application of a sufficiently high dose of radiation, some individuals exhibit a syndrome usually referred to as "roentgen sickness" which, clinically, is not unlike seasickness In some patients a relatively small amount of radiation (100 r) will produce these symptoms, while others may not show them even under intense irradiation. Treatment of the abdominal region seems to be more likely to produce the difficulty, but it may arise after any type of irradiation. Numerous efforts have been made to find the cause of this systemic reaction, which must be due in some way to flooding the organism with products of cell destruction following irradiation Clark summarizes the explanations which have been offered—none of which has been proven—as follows: "Explanations advanced include lowering of sodium chloride content in blood serum (in many cases injection of 5 per cent salt solution has been effective); decrease in cholesterol content, increase in calcium and decrease in potassium, nitrogen increase in blood, changes in protein, changes in blood sugar, increase in blood coagulability, change in sedimentation rate of red blood corpuscles; release of "H" substance from injured cell, etc A highly important and interesting recent discovery is that the injection of 1 cc of liver extract is very effective in eliminating this effect."

Stimulating Effect of Irradiation.—Among the early investigations of biologic effects of radiation were many in which the experimental conditions were not carefully controlled. The results of some of these indicated that small doses stimulated growth and larger ones retarded it This idea was in accordance with the known behavior of certain drugs, in which small doses accelerate and larger ones retard certain functions, and it gained ready acceptance However, careful experiments have never detected an actual stimulating effect, for any dose whatever There is undoubtedly a transitory acceleration of certain physiologic processes, but this continues for only a short time, and is followed by a compensating period of quiescence, even when lasting injury is not produced. *Radiations are always injurious to the cells which absorb them*

The Effect on Hereditary Material.—Ever since Albers-Schoenberg, in 1903, discovered the sterilizing effect of x-rays, there has been argument regarding the question of whether irradiated germ cells which escape complete destruction may be so altered as to have changes produced in the hereditary material Such changes would have far-reaching significance, both from the point of view of producing and

transmitting undesirable characteristics in the human race, and of purposefully modifying plant and animal organisms

Actual demonstration of inheritable changes is very difficult because of the complicated nature of the genes and their behavior Many reports based on the observation of only a few individuals for two or three generations must be considered worthless However the brilliant work of H J Muller on Drosophila eggs shows beyond question that in this organism hereditary changes can be effected by irradiation Other workers have shown analogous results with numerous plant and animal subjects

There is no way of controlling the changes produced and the great majority of them are detrimental All of the mutations which have been observed after irradiation are also observed in Nature, but a very small amount of radiation makes the appearance of changes in the irradiated group many times more frequent than in the controls

This question is of great significance in radiotherapy because of the possibility of damaging the hereditary material in the course of treatment The following quotation from Muller emphasizes this danger

'If irradiation causes an increase in the mutation frequency of man similar to that in Drosophila, then it would take an average of only 30 or 40 roentgens per individual to make the rate at which hereditary weaknesses and lethals are produced double the natural rate

' Of course, such effects could be produced only if the reproductive organs received the radiation and if reproduction occurred subsequently to this We must remember that the effect is exactly proportional to the amount of energy received and exactly cumulative over an indefinitely long period Thus if the germ cells received only a little secondary radiation not enough to cause infertility or any noticeable physiological reaction but received this repeatedly at widely separated intervals even in successive generations the final effect would be the production of mutations as great as though the whole treatment had been given at once

This last statement is based on the assumption that the human genes are affected by irradiation in the same way as those of the Drosophila In no other human tissue has this type of exact cumulation been found However, even granting the possibility of considerable recuperation it is evident that the danger still exists In any given case it is impossible to prove that the production of physically or mentally affected offspring is to be directly attributed to irradiation

Bactericidal Effect —The earliest biologic experiments within a few months after the discovery of x-rays were a search for a bactericidal effect Bacteria in pure cultures can be killed with sufficiently large doses of radiation Most of them are, however so resistant that any attempt to destroy them as a clinical measure would require doses which would be dangerous or even lethal for their hosts

The Relation of Quality of Radiation to Biologic Effect —Early experiments on the effects of different qualities of radiation seemed to show

differences between the results of treatment with hard and soft rays, so that beta rays and soft x-rays came to be spoken of as *caustic*, in contrast to the so-called "healing" effect of hard rays. With the availability of instruments for measuring dosage more carefully, it has been found that in many cases what was thought to be a difference due to the quality of the radiation could be attributed to different doses or different *intensities*. We are concerned with the effect of equal doses of radiation of different qualities, delivered in equal times. Based on experiences with various biologic materials such as fruit fly eggs, plants, etc., it would seem that biologic effects are not dependent upon ray qualities, but upon the quantity of radiation administered One is justified in assuming that the behavior of small eggs or seeds suspended on gauze under the x-ray tube will be different from the entire animal (or human) with its interrelated tissues, changing blood supply, and the complications of back-scattered radiation

Chemical and Biochemical Effects.—It seems apparent that changes in the life cycle of the cell must be due to some changes in its constituents That is, ultimately, the basis for investigation must not be the entire cell, but the individual molecules In the effort to understand the alterations which may take place in these fundamental units, many chemical and biochemical researches have been carried out. A large number of chemical reactions are brought about, or hastened, by the action of radium or roentgen rays Little mention need be made here of the numerous ones which probably have no relation to biologic changes The most important of them are the action on photographic emulsions, the liberation of iodine from solutions of iodides, the oxidation of ferrous sulfate, and the precipitation of mercurous chloride from Eder's solution

More significant are such changes as the decomposition of water into hydrogen and oxygen, the synthetization of hydrogen peroxide from water having oxygen in solution, the oxidation of oxyhemoglobin to methemoglobin, the precipitation of proteins and the inactivation of enzymes

With the exception of the photographic effects, most of these reactions require large doses of radiation for the transformation of an appreciable percentage of the material present It may be that the biologic changes result from very slight partial transformations of a number of different chemicals present in the cell Or it may be that the breaking down of only a few of the very complex organic molecules starts a whole train of subsidiary reactions

Mode of Action of Radiation on Cells.—It must be accepted that whatever changes are produced result from a transfer of energy from the radiation to the irradiated material. The fundamental postulate of the action of radiation (known as the law of Grotthus and Draper) states that *only the energy which is absorbed can be effective in producing any reaction* Therefore the question is how the absorbed energy acts upon the cell molecules.

As has been seen in Chapter VIII the first result of the impact of radiation on matter is the production of *secondary radiation* in the form of fast moving electrons. These electrons *ionize* atoms in their paths. The ionized atom is temporarily in an abnormal condition, and while in this state it lends itself readily to entering into new combinations. Ionization of the individual atom lasts only a very short time. If however enough of them are ionized simultaneously a large enough percentage of the cell constituents may undergo transformation so that an apparent change is produced. This theory has been elaborated by Holthusen, Lacassagne and others.

A different point of view is that held by Dessauer. He considers that the point of actual attack in the cell is the large protein molecule, and that cell changes are brought about not by chemical transformations but by an actual coagulation analogous to the action of heat. The energy absorbed by the tissues even for very large doses of radiation is very small in comparison to the amount necessary to produce complete coagulation of the aggregate of molecules in the cell. Dessauer avoids this difficulty by his point heat hypothesis. He assumes that there must be a certain number of direct impacts of secondary electrons with atoms which result not in ionization but in actual increase in the velocity of the entire atom, a *warming up*. (It should be remembered that increase in temperature actually only means increase in atomic or molecular velocities within the solid matter.) He considers that if a sufficiently high percentage of the molecules of a given cell—1/100 to 1/10—are thus warmed up, coagulation will result.

Failla has offered the most helpful theory for the action of radiation on the cell and its nucleus. It combines features of both above mentioned concepts and builds from them a really workable hypothesis. He suggests that a certain portion of the cell proteins are broken down during the radio ionization into simpler substances of the type which dissociate or ionize, electrolytically (see Chapter III). When this occurs the ion concentration of the fluids both inside and outside the cell increases. The fluids outside the cell are diluted or carried away by the circulation, those inside cannot be thus affected. In the effort to equalize the concentration inside and outside the semi permeable cell wall, fluid will enter the cell causing it to swell. This process will be hastened if the membrane has itself been weakened by direct hits. Subsequently a similar effect takes place within the nucleus as the cell fluids outside the nucleus become more dilute than those inside, by the process just mentioned. The swelling of the cell and of the nucleus are well known radiation effects. By his theory Failla is able to explain various other phenomena connected with irradiation, *e g* delayed reactions, variations in sensitivity with cell structure and with vascular supply, variation in erythema dose with quality of radiation, etc. It does not explain hereditary effects but Failla supposes that these represent a different type of reaction, probably direct hits on the chromosomes.

It is apparent that much additional information is necessary before all the phenomena of radiation reactions can be understood. New contributions are constantly being made to the problem, and it is to be hoped that in the near future they will be extended and correlated to provide a satisfactory background for problems of radiation therapy

BIBLIOGRAPHY

ADLER, K Die biologische Wirkung der kurzwelligen Strahlen auf den Stoffwechsel der Zelle, Strahlentherapie, **36**, 1, 1930

ALBERS-SCHOENBERG, H Ueber eine bisher unbekannte Wirkung der Roentgenstrahlen auf den Organismus der Tiere, Münch. med. Wchnschr, **50**, 1859, 1903

BERGONIÉ, J, and TRIBONDEAU, L Interprétation de quelques résultats de la radiothérapie, Compt rend Acad d sc, **143**, 983, 1906

BRAUN, R, and HOLTHUSEN, H Einfluss der Quantengrösse auf die biologische Wirkung verschiedener Roentgenstrahlenqualitaten, Strahlentherapie, **34**, 707, 1929.

BUTLER, E G. On Some Cellular Reactions of X-radiation, Jour. Exp Biol, **9**, 107, 1932

CANTI, R G Biological Effects of Radium Irradiation, Acta Radiologica, **10**, 320, 1929

CLARK, GEORGE L A 1936 Survey of the Biological Effects of X-radiation, Radiology, **26**, 295, 1936.

COLWELL, HECTOR A The Method of Action of Radium and X-rays on Living Tissues, Oxford University Press, 1935

DESJARDINS, A U Radiosensitiveness of Cells and Tissues, and Some Medical Implications, Arch Surg, **25**, 926, 1932

——— Radiotherapy for Inflammatory Conditions, Jour Am. Med Assn, **116**, 225, 1941

DESSAUER, F Strahlung und Lebensvorgange, *Zeitschr f Krebsforschung*, **35**, 287, 1932

DUNLAP, C. E Effects of Radiation on the Blood and the Hematopoietic Tissues, including the Spleen, the Thymus and the Lymph Nodes, in Warren, S, Effects of Radiation on Normal Tissues, Arch Path, **34**, 562, 1942.

DUSTIN, A P, PITON, R, and ROCMANS, P Étude comparative des altérations histologiques et des variations du pH sanguin après irradiation, Compt rend. Soc d Biol, **107**, 1562, 1931

ELLINGER, FRIEDRICH The Biologic Fundamentals of Radiation Therapy, New York, Elsevier Publishing Company, 1941

FAILLA, G A Theory of the Biological Action of Ionizing Radiations Some Fundamental Aspects of the Cancer Problem Supplement to Science, **85**, 202, 1937

FAILLA, G, *et al* · Relative Effects Produced by 200 kv Roentgen-rays, 700 kv. Roentgen-rays, and Gamma Rays, Am Jour Roentgenol and Rad Ther., **29**, 293, 1933

FRIEDMAN, N B Effects of Radiation on the Gastrointestinal Tract, including the Salivary Glands, the Liver and the Pancreas, in Warren S, Effects of Radiation on Normal Tissues, Arch Path, **34**, 749, 1942

GATES, O Effects on Bone, Cartilage and Teeth, Chapter XII in Warren, S, Effects of Radiation on Normal Tissue, Arch Path, **35**, 323, 1943

GLASSER, OTTO Medical Physics, Chicago, The Year Book Publishers, 1944

MULLER, H J The Effects of Roentgen-rays Upon the Hereditary Material, in Glasser, O, ed, The Science of Radiology, Charles C Thomas, 1933, p. 305

PACKARD, C Biologic Effects of Roentgen-rays and Radium, in Glasser, O, ed., The Science of Radiology, Charles C Thomas, 1933, p 319

SAXE, E Die Aenderung der biologischen Wirksamkeit von Membranen unter den Einfluss von Roentgenstrahlen, Strahlentherapie, **40**, 125, 1931

SCHECHTMANN, J, and KLUPFEL, W Beitrag zur Wirkung der Roentgenstrahlen auf die biologischen Gewebe, Strahlentherapie, **43**, 792, 1932

STRANGEWAYS, T S P, and HOPWOOD, F L Effect of X-rays Upon Mitotic Cell Division in Tissue Cultures *in vitro*, Proc Roy Soc, London, S B **100**, 283, 1926

V ERHELLER, F, and SARALEGUI, J A Roentgenwellenlange und biologischer Effekt, Strahlentherapie, **38**, 641, 1930

WARREN, SHIELDS Effects of Radiation on Normal Tissue, Arch Path, **34**, 443, 562, 749, 917, 1070, 1942, and **35**, 121, 304, 1943 Chapter 3 was written by C E Dunlap, Chapter 4 by N D Friedman, and Chapter 12 by O Gates

The monograph of Ellinger, and the chapters of Muller and Packard in The Science of Radiology, contain very extensive bibliographies.

CHAPTER XX

EFFECT OF X-RAYS AND RADIUM ON NORMAL ANIMAL ORGANS AND TISSUES

In this chapter we give no more than a condensed outline, with essential or basic information of the effect of x-rays and radium on animal organs and tissues. For greater detail the reader is referred to a dissertation and compilation with complete literary review to 1944, by Shields Warren and collaborators, an excellent monograph by Frederick Ellinger and a book edited by Ernst A. Pohle, also, a series of articles by Desjardins. These references are in the bibliography at the end of this chapter.

As was mentioned in the preceding chapter, each variety of cell in the body has a specific range of sensitiveness to x-rays or radium. Some cells such as the leukocytes (especially the lymphocytes and polymorphonuclear cells) are most susceptible to irradiation, while other cells, especially the nerve cells, are highly resistant. Between these two extremes the other varieties of cells can be arranged, according to their vulnerability, in a definite order:

Lymphoid cells (lymphocytes in the spleen, lymph nodes, intestinal lymph follicles, circulating blood, bone marrow, thymus, tonsil and other structures in which such cells may be present).

Polymorphonuclear leukocytes and eosinophils in the blood or tissues.

Epithelial cells: (1) basal epithelium of certain secretory glands, especially the salivary glands; (2) basal epithelium (spermatogonial cells) of the testis and follicular epithelium of the ovary; (3) basal epithelium of the skin, mucous membranes and certain organs, such as the stomach and small intestine; (4) alveolar epithelium of the lungs and epithelium of bile ducts (liver) and (5) epithelium of tubules of the kidneys.

Endothelial cells of blood vessels, pleura and peritoneum.
Connective tissue cells.
Muscle cells.
Bone cells.
Fat cells.
Nerve cells.

By "specific range of sensitiveness" is meant that, when exposed to the same dose of rays under the same conditions, some cells are influenced more rapidly and to a greater degree than other kinds of cells. At any particular time, however, all cells of one kind are not affected to the same degree by the same dose of rays. This is because the sensi-

tiveness of different cells varies according to the phase of metabolism in which they happen to be at the time of irradiation Cells that are actively dividing are more sensitive than cells during the intermitotic or resting phase Any factor which increases the rate of mitosis (hyperplasia) tends to increase the radiosensitiveness of the cells. The sensitiveness of different kinds of cells is closely related to their degree of differentiation and to their life cycle.

Lymphoid Cells and Tissues.—Of the different kinds of cells, the lymphocytes in the spleen, lymph nodes, tonsils, and circulating blood are the most sensitive When a structure containing many lymphocytes is exposed to even a moderate dose of rays, many of these cells rapidly degenerate and disappear After a large dose the disintegration of lymphocytes is so rapid that it has been likened to an explosion. First the chromatin material of the nuclei breaks up into fragments and, the protoplasm undergoing liquefaction, the cells disintegrate and the fragments of nuclear chromatin are scattered among the remaining intact cells. Then some of the reticular cells assume a phagocytic property and ingest the fragments of chromatin, which undergo intracellular digestion. As the destruction of lymphocytes proceeds so many cells may be affected that only the connective tissue remains. After a variable period of time, the remaining lymphocytes which have not been injured beyond recovery multiply and, depending on the dose of rays, partial or complete restoration of these cells may occur. After repeated irradiation, lymphocytic recovery may be slight or *nil*.

This effect was first observed experimentally by Heineke and by Rudberg. Since then many others have confirmed the exceptional sensitiveness of lymphocytes

Tonsils.—Being made up of lymphoid tissue (chiefly lymphocytes and varying degrees of connective tissue according to age), the tonsils, like other lymphoid structures, are quite sensitive to *x*-rays or radium

Thymus.—This gland is both an endocrine organ and a producer of lymphocytes. Heineke in 1905 reported that the normal thymus is radiosensitive. The radiosensitivity is about intermediate between the spleen and the lymph nodes The hyperplastic thymus is more radiosensitive than is the normal organ. Hyperplasia of the thymus in early life, the so-called thymicolymphatic state, can often be corrected by irradiation

Blood and Hematopoietic System.—It has long been known that *x*-rays are capable of reducing the leukocyte count in leukemic as well as in normal blood This fact was first noted in 1903 by Pusey and Caldwell and by Senn This information caused considerable perturbation and practically all roentgenologists had their blood examined The result, fortunately, was such as to negative the justifiable alarm. There were a few instances of lowered erythrocyte and leukocyte counts, but in this respect the variations among roentgenologists were no greater than among average individuals of various occupa-

tions In this connection Benjamin, v Reuss Sluka and Schwarz found evidence of injury to the hematopoietic system in 10 roentgenologists who had been exposed to x rays over long periods of time They also cited 2 fatal cases of leukemia among roentgen-ray workers and one in a chemist engaged in the production of radium Mottram and Clarke found leukopenia in persons who had been exposed to radium Several cases of pernicious anemia have also been reported

Physicians and others who employ x rays or radium for medical purposes and who therefore may be exposed to these agents at frequent intervals may and not infrequently do suffer ill effects One of the earliest evidences of injury from this cause is leukopenia especially lymphopenia Because of the shorter distance at which it is commonly employed, and often because of careless handling radium is more dangerous than x-rays

Thanks to the experimental work of Helber and Linser Benjamin v Reuss Sluka and Schwarz Latarsky Tamubin Thomas and Bruner and others it is now known that large doses of x-rays administered to animals cause a decrease in the number of leukocytes in the circulating blood In fact if the exposure is of sufficient strength the blood may even become entirely free of white cells before death The lymphocytes are the most susceptible the polymorphonuclear cells less sensitive and the erythrocytes least of all

The polymorphonuclear leukocytes are somewhat less sensitive than the lymphocytes After irradiation the former cells often exhibit a peculiarity of reaction practically never seen with lymphocytes For a short time after exposure to x rays or radium the number of polymorphonuclear cells in the blood may increase rapidly but this increase seldom lasts more than twelve or eighteen hours after this their number steadily diminishes and falls below the normal level where it may remain from a few days to three or more weeks according to the dose of rays Gradual regeneration then takes place When irradiation has been repeated many times however regeneration of the polymorphonuclear cells may be slow and may never be complete

Mature erythrocytes are much less sensitive than leukocytes in fact they are less sensitive than many other kinds of cells Even immature red corpuscles are less susceptible than lymphocytes or polymorphonuclear cells Repeated irradiation of long bones (bone marrow) and relatively large doses of rays are required before a definite reduction in the number of erythrocytes can be observed When the erythrocyte-forming centers are not exposed to direct irradiation it is surprising how little these cells may be affected

Routine radiation therapy in dermatology seldom if ever produces dangerous or permanent changes in the blood or the hematopoietic organs However general body irradiation for generalized dermatoses may cause an injurious diminution of white cells and even of erythrocytes (Pascher and Kanee and others) Also an abnormal blood picture may be caused by prolonged irradiation over any part of the

hematopoietic system—long bones, spleen, thymus, etc. During the past thirty years a large number of cases of leukemia, aplastic and other types of anemia, agranulocytosis and purpura, have occurred in radiologic workers and in radium and *x*-ray industries.

There has been an enormous amount of research on the chemical and biologic effect of irradiation on the various blood components. The literature is voluminous and the results interesting and instructive. All such details are in the works enumerated at the beginning of this chapter.

Salivary Glands.—According to Desjardins, next to the leukocytes, the salivary glands are most sensitive to *x*-rays or radium, they are more sensitive than the genital glands Within six hours after a sufficient dose the irradiated glands swell and the secretion of saliva diminishes. Within the glands, the mucus-secreting epithelium undergoes mucoid degeneration, the cells swell, the secretion thickens, and the excretory ducts become occluded. These changes continue for from twelve to forty-eight hours, after which they gradually subside and disappear. The changes mentioned affect only the glands on the irradiated side of the face If both sides have been exposed to a large dose of rays, dryness of the mouth may become evident and may continue for some time; this is especially true after repeated irradiation.

We know that the routine amount of *x*-rays used for acne vulgaris, namely, 75 r weekly for a maximum of sixteen weeks, has no objective or subjective effect on the salivary glands

Testis.—In 1905 the medical profession was startled by Brown and Osgood's report of 18 radiologists who were subjects either of azoospermia or oligonecrospermia. Antedating this publication by one year, Philipp recorded the sterilization of 2 men by *x*-rays which had been applied to the perineal region for the treatment of pruritus ani and orificial tuberculosis

The cells of the seminiferous tubules are very sensitive to irradiation and the early chemical and morphological changes have been of great interest to embryologists, physiological chemists, biologists, etc

Depending on the size of the dose, *x*-rays and radium may cause partial or complete sterility, temporary or permanent, with or without modification of sexual potency. Ellinger calls attention to reversible and irreversible reactions. The first is temporary sterilization which usually requires a dose of 200 or 300 r, but which may follow the administration of 60 r The irreversible reaction is permanent sterility (total castration) which requires a dose of at least 500 or 600 r

Ovary — *X*-rays and radium in sufficient dosage may cause the complete disappearance of the Graafian follicles, with more or less atrophy of the entire organ As with the testes, the effect may be partial or complete, temporary or permanent, depending upon the amount of exposure The effect of irradiation on the ovary was first noted by Halberstadter in 1905, later by Sarezki, Maury and others. The

susceptibility of ovarian tissue to the influence of *x* rays forms the basis for the well known roentgen treatment of menorrhagia and uterine fibroid, as originally conceived by Albers-Schonberg and confirmed by others. It is possible to effect an artificial menopause by the application of *x*-rays, radium or a combination of the two agents, without injury to the skin or other abdominal tissues. The amount and quality of irradiation advisable in the treatment of cutaneous diseases is never sufficient to bring about sterility nor to endanger the ovaries.

Temporary sterilization (reversible reaction) requires about 170 r at the ovary. According to Ellinger, based upon research by Martins, Krönig Friedrich and Peck, 290 r at the ovary will cause permanent amenorrhea with survival of endocrine function. A single dose of about 320 r or 620 r fractionated, at the ovary, will destroy all ovarian functions.

Lungs.—In comparison with the preceding structures the lungs are only slightly radiosensitive (Desjardins and others). Ordinary therapeutic doses such as are used in dermatology have no effect on them. But when, as in the treatment of a malignant lesion of the breast or thorax, heavy dosage is employed the underlying pleura and lung may suffer temporary or permanent injury. On the whole, the lungs are less sensitive than the small intestine.

The tendency to ascribe to *x*-rays or radium any clinical disturbance arising after exposure to these agents is often unwarranted. Pleuritis or *pneumonitis with subsequent pulmonary fibrosis may result from* strong irradiation, but it should be remembered that these complications may also result from causes which have nothing to do with irradiation. Pulmonary fibrosis was well known and fairly common long before *x* rays were discovered. When reactive inflammation of the lungs is due to the rays the clinical manifestations arise from fourteen to twenty-eight days after exposure of the corresponding fields, and the dose must have been sufficient to cause at the same time a rather pronounced reaction of the overlying skin unless the treatment was given with highly filtered rays generated at potentials between 200 and 1000 kv.

Digestive System.—The sensitiveness of the salivary glands has already been mentioned. As for the stomach it is only moderately sensitive, ordinary therapeutic irradiation having little if any perceptible effect. Experiments on animals have shown that large doses may cause the secretion of acid and of pepsin to diminish for a time and, after repeated exposure the amount secreted tends to be smaller and smaller, but after a variable period of time the gastric secretion again increases thus showing that the gastric epithelium has not been injured beyond repair.

The small intestine is the most radiosensitive portion of the gastro-intestinal tract. It is considerably more sensitive than the large intestine or stomach. Moreover, the duodenum and jejunum are more sensitive to irradiation than the remainder of the small intestine.

A large total dose of rays through a single field or through the convergence of several beams directed to separate fields, provided these fields include a portion or all of the small intestine but especially the duodenum or jejunum, may be followed by more or less severe enteritis. Experiments on animals have shown that excessive exposure causes congestion, edema, degeneration and desquamation of the epithelium lining the affected portion of bowel and, if the injury is sufficiently severe, the foregoing changes may be followed by atrophy of the secreting glands and sometimes by constriction of the gut by connective tissue laid down to repair the injury The experiments of Krause and Ziegler, Regaud, Nogier and Lacassagne, Fromme, Hall and Whipple, Denis, Martin and Aldrich, Warren and Whipple, Martin and Rogers, and others, amply substantiate these conclusions.

In the everyday practice of radiotherapy, however, even with the doses of rays employed in treating uterine fibromyomas and malignant tumors of the abdominal viscera, serious injury to any part of the gastrointestinal tract seldom occurs.

Pancreas.—The pancreas may be temporarily injured by an erythema dose applied over the abdomen, but its power of regeneration compensates for this in a short time This is borne out by the experiments of Orndoff, Farrell, Ivy, Terbrüggen and Heinlein on dogs, in which the region of the pancreas was irradiated. They found that one-tenth of a human erythema dose increased the concentration of lipase and trypsin but did not affect the quantity of secretion After one-half an erythema dose, both the quantity of secretion and amount of ferments increased. One human erythema dose decreased the quantity of secretion and the total output of ferments Return to normal ensued

Blood Vessels.—A great deal of research has been undertaken during the past few years to explain both the early and late ectasia of the capillaries of the skin following an erythema dose of *x*-rays. David studied the capillaries with a diascope after irradiation and found the contractile elements of the capillary walls first affected Functionally the tonus of the capillary walls was reduced, with resulting dilatation Lazarew and A. Lazarewa, experimenting on rabbit ears, found a definite increase in the irritability of the vasodilator apparatus in the irradiated ear, as compared with the nonirradiated ear Siedamgrotsky studied the capillaries of the skin after an erythema dose He used epinephrine to produce contraction and mustard oil and caffein to produce dilatation. His results follow

1 On the second day following irradiation, there was an increased ability to constrict and also an ability to dilate, but to a lesser degree

2. On the sixth day, the power to constrict remained very high but ability to dilate was not much above normal.

3. On the eighth and ninth days, increased reddening was present, with a still greater constriction, dilatation was about constant in relation to normal skin.

4 After a long period of time the skin capillaries appeared to have undergone permanent injury of the constricting and dilating powers properties closely related to Rouget cells which the writer concluded were robbed of their ability to alter their tonus when subjected to external stimuli This injury did not affect the nervous apparatus, but only the Rouget cells

The late ectasia of the cutaneous blood vessels following an erythema dose or over, is attributed by Fabry to two factors (1) atrophy of the upper layers of the epidermis, with resulting exposure of the blood vessels of the cutis, and (2) secondary proliferation of the vessels themselves The microscopic alterations in and around the blood vessels, subsequent to irradiation, are discussed in the Chapter on *Pathologic Histology of Radiodermatitis*

Liver —The liver seems to be quite radiosensitive Case and Warthin believe that the epithelium of the biliary tract is about as susceptible to x rays as the gastrointestinal mucosa, but the evidence indicates that, although the epithelium lining the bile ducts appears to be slightly more sensitive than the hepatic cells, the radiosensitiveness of the liver as a whole is much less than that of intestine Bromeis in a study of patients submitted to the action of x-rays found urobilinogen in the urine in 74 per cent of cases after treatment and in 69 per cent of cases after radiography The part of the trunk irradiated made no difference in the findings He attributed this to an injury of the liver resulting from toxic products of cell destruction Dodds and Webster found a decreased blood urea after irradiation of the abdomen due perhaps, to a temporary inhibition of the metabolic functions of the liver

Bentel states that the liver reacts to doses of 150 r Ellinger quoting Bentel, avers that 550 r produce reversible changes that may play a role in radiation sickness With 2500 r, in rats, Pohle and Bunting produced severe histologic changes but recovery took place in a month

Kidney —The kidney is only moderately sensitive to x-rays or radium much less than the spleen and lymphoid structures the leukocytes in the circulating blood the testis or ovary, or even the small intestine and lungs Certain experiments on animals have shown that the kidneys like every other organ in the body, can be injured if exposed to excessive doses of rays, but in the experiments mentioned the doses used were much larger than those ordinarily employed in treating human beings The experimenters were not seeking to determine the limit of tolerance of the kidneys but were deliberately trying to induce chronic nephritis In view of the doses of rays to which the kidneys of their animals were subjected, it is not surprising that they succeeded but to conclude that exposure of the kidney to ordinary therapeutic irradiation is a dangerous procedure is unwarranted

Eye —Desjardins, Leinfelder and Kerr, Ellinger Jones and Alden and others have reported experimental and clinical results of irradia

tion on the eye. Exposure of the fetus (*in utero*) to a sufficient dose of *x*-rays may induce pathologic changes characterized by retardation of growth of the eyeball and by degeneration of the crystalline lens, leading to cataract. Similar changes may occur after birth if the rapidly developing eye of an animal or child is irradiated during early life.

The mature eye of adults is much less sensitive to irradiation, less sensitive, in fact, than the eyelids. Therefore, a single dose of *x*-rays insufficient to cause an inflammatory reaction of the lids and conjunctiva is not likely to have an unfavorable influence on the other ocular structures. Long-continued irradiation is inadvisable There have been, in clinical work, a number of cases of cataract allegedly caused by irradiation.

Mammary Glands.—Long-continued irradiation of the mammary glands is likely to reduce the activity of the secreting epithelium (Cluzet and Bassal).

Conservatism is urged by Davis in the treatment of carcinoma of the breast and other superficial malignant lesions of the thoracic wall with *x*-rays He produced acute and chronic changes in the lungs and pleura of normal dogs after intensive roentgen treatment Others have described similar, though less marked, effects in human beings after strong irradiation of the thorax. As a result of research by Turner and Gomen, Ellinger estimates that a dose of 1400 r is likely to injure the mammary gland

Thyroid.—Irradiation of the thyroid gland may inhibit secretory function, but little alteration may be observed microscopically. This is especially true when the overactive function is due to or associated with cellular hyperplasia, probably because the increased rate of mitosis incidental to hyperplasia makes the cells lining the acini more radiosensitive than when the cells are dividing at the normal rate In practical work it is often possible to overcome the symptoms of hyperthyroidism, but the gland, if enlarged, rarely undergoes reduction in size (Pfahler and Zulick, Dowd and others). In toxic hyperthyroidism a moderate quantity of the rays may cause a decrease in the secretion For simple adenoma roentgen therapy is not indicated Normal thyroid tissue is radioresistant. It requires 600 r or more to produce morphologic changes. Excessive irradiation may cause myxedema (Ellinger).

Suprarenals.—Certain authors have reported cases of assumed injury to the suprarenal glands by excessive irradiation, but critical analysis of such cases makes the assumption doubtful Judging by the experimental evidence, the suprarenal glands are rather resistant to irradiation, and the weight of clinical evidence supports this view In the cases cited as examples of radiation injury, the suprarenal damage was probably caused by cancer and not by *x*-rays No injury to these glands was noted with an erythema dose, but 3000 r caused substantial alteration in all parts of the suprarenals (Engelstad and Momigliano).

Pituitary—The pituitary gland is radioresistant, especially in adults. Experimentally, it is possible to obtain a suppression of growth and sex function, with histologic change, by irradiating the pituitary gland, but approximately 2000 r are required.

Nervous System—Irradiation of the pregnant uterus may, if the dose of rays is sufficient, retard more or less the growth of the fetal skull and secondarily that of the brain itself; it may even cause death of the fetus and result in abortion or miscarriage. Exposure of the head of an infant to a sufficient dose of rays also may retard the growth of the irradiated portion of the skull and, if the entire head has been exposed, may lead to secondary nervous phenomena. The degree of interference with the growth of the skull depends on the age of the child and on the dose of rays. With small doses a deleterious effect is not likely to occur. After five years of age, any interference with the growth of the cranial bones or secondary nervous phenomena is not so likely to occur even after rather large doses of *x*-rays or radium.

In adults the brain, the spinal cord, and the nerves in general are extremely resistant to irradiation. Pathologic alterations in these structures have been observed microscopically after exceptionally large doses, but these were probably secondary to alterations in the blood vessels, which are more susceptible to irradiation than nerve tissue itself.

Over a period of thirty or more years many thousand children, between the ages of three and eight, have at one sitting received to the head five epilating doses of unfiltered *x*-rays (1500 r, at times 2000 r) for the treatment of tinea capitis. There has not been a single report of damage to the nervous system or to the cranial bones by such treatment.

BIBLIOGRAPHY

ALBERS-SCHONBERG, H.: Ueber eine bisher unbekannte Wirkung der Rontgenstrahlen auf den Organismus der Tiere. Munchen med Wchnschr 50: 1859, 1903.

BENJAMIN, E., v. REUSS, A., SLUKA, E., and SCHWARZ, GOTTWALD: Beitrage zur Frage der Einwirkung der Rontgenstrahlen auf das Blut. Wien klin Wchnschr 19: 788, 1906.

BEUTEL, A.: Zur Beeinflussung der Leberfunktion durch Roentgenstrahlen. Strahlentherapie 45: 344, 1932.

BROMEIS, HEINZ: Urobilinogenausscheidung im Harn nach Rontgenbestrahlung und Durchleuchtung. Strahlentherapie 23: 687, 1926.

BROWN, F. T., and OSGOOD, A. T.: X-Rays and Sterility. Am Jour Surg 18: 179, 1904–1905.

CASE, J. T., and WARTHIN, A. S.: The Occurrence of Hepatic Lesions in Patients Treated by Intensive Deep Roentgen Irradiation. Am Jour Roentgenol and Rad Ther 12: 27, 1924.

DAVID, O.: Untersuchungen uber den Einfluss von Rontgenstrahlen auf Kapillaren. Strahlentherapie 23: 366, 1926.

DAVIS, K. S.: Intrathoracic Changes Following X-Ray Treatment. A Clinical and Experimental Study. Radiology 3: 301, 1924.

DENIS, W., MARTIN, C. L., and ALDRICH, MARTHA: A Study of the Relative Toxic Effects Produced by Regional Radiation. Am Jour Med Sci 160: 555, 1920.

DESJARDINS, A. U.: The Reaction of the Pleura and Lungs to Roentgen Rays. Am Jour Roentgenol and Rad Therapy 16: 444, 1926.

———: Action of Roentgen Rays and Radium on the Eye and Ear. Ibid 26: 639, 787, 1931.

DESJARDINS, A U Radiosensitiveness of Cells and Tissues, and Some Medical Implications, Arch Surg, 25, 926, 1932
———— The Action of Roentgen Rays or Radium on Inflammatory Processes, Radiology, 29, 436, 1937
———— Dosage and Method of Roentgen Therapy for Inflammatory Conditions, Ibid, 32, 699, 1939
———— Radiotherapy for Inflammatory Conditions, Jour Am Med Assn, 116, 225, 1941
DODDS, E C, and WEBSTER, J H D. Metabolic Changes Associated with X-Ray and Radium Treatment, Lancet, 1, 533, 1924
DOWD, C N. Goiter, An Analysis of One Hundred and Thirty-seven Cases, Jour Am Med Assn, 66, 480, 1916
ELLINGER, F The Biologic Fundamentals of Radiation Therapy, English Translation by Reuben Gross, New York, Interscience Publishers, Inc, 1941
ENGLSTAD, R B Histologische Veranderungen in den Nebennieren nach Roentgenbestrahlung, Strahlentherapie, 56, 58, 1936
FABRY, JOH Entstehung und Entfernung der oberflachlichen Gefassektasien nach Rontgen-, Radium- und Mesothoriumbestrahlung, Med Klin., 22, 1408, 1926
HALBERSTADTER, LUDWIG Die Einwirkung der Rontgenstrahlen auf Ovarien, Berl klin Wchnschr, 42, 64, 1905
HALL, C C, and WHIPPLE, G H. Roentgen-Ray Intoxication, Disturbances in Metabolism Produced by Deep Massive Doses of the Hard Roentgen Rays, Am Jour Med Sci, 157, 453, 1919
HARTMAN, F W, BOLLIGER, A, and DOUB, H P Experimental Nephritis Produced by Irradiation, Ibid, 172, 487, 1926.
———— Functional Studies Throughout Course of Roentgen Ray Nephritis in Dogs, Jour Am Med Assn, 88, 139, 1927
HEINEKE, H Ueber die Einwirkung der Rontgenstrahlen auf Tiere, Munchen med Wchnschr, 50, 2090, 1903
———— Zur Kenntnis der Wirkung der Radiumstrahlen auf tierische Gewebe, Ibid, 51, 1382, 1904
———— Experimentelle Untersuchungen uber die Einwirkung der Rontgenstrahlen, auf innere Organe, Mitt a d Grenzgeb d Med u Chir, 14, 21, 1904–1905
HELBER, E, and LINSER, P Experimentelle Untersuchungen uber die Einwirkung der Rontgenstrahlen auf das Blut, Munchen med. Wchnschr, 52, 689, 1905
JONES, J W, and ALDEN, H S Roentgen Ray Treatment of the Eye, Arch Dermat and Syph, 43, 92, 1941
KRAUSE, PAUL, and ZIEGLER, KURT Experimentelle Untersuchungen uber die Einwirkung der Rontgenstrahlen auf tierisches Gewebe, Fortschr a d Geb d Rontgenstrahlen, 10, 126, 1906
LAMBIN, P Les anémies provoquées par les rayons X et les corps radioactifs, Rev belge sc méd, 2, 623, 1930
LAZAREW, N W, and LAZAREWA, ANNA Ueber die funktionellen Veranderungen der Blutgefasse nach Rontgenbestrahlung I Mitteilung Pharmakodynamische Untersuchungen des funktionellen Zustandes der Gefasse isolierter Kaninchenohren nach vorhergehender Bestrahlung *in vivo*, Strahlentherapie, 23, 41, 1926
LEINFELDER, P J, and KERR, H D Roentgen-Ray Cataract, Am Jour Ophthal, 19, 739, 1936
MARTIN, C L, and ROGERS, F T Intestinal Reaction to Erythema Dose, Am Jour Roentgenol and Rad Ther, 10, 11, 1923
———— Roentgen-Ray Cachexia, Ibid, 11, 280, 1924
MAURY, J M Results of Exposure of Animal Ovaries to Rays of Radium, Jour Am Med Assn, 74, 1711, 1920
MOMIGLIANO, E Riflessi endocrini dell' irradiazione ipofisaria, Ann di ostet e ginec, 60, 1061, 1938
MOTTRAM, J C, and CLARKE, J R The Leucocytic Blood-Content of Those Handling Radium for Therapeutic Purposes, Arch Radiol and Electroth, 24, 345, 1920, also in Proc Roy Soc Med (s Electro-Therap), 13, 25, 1920, Abstr, Am Jour Roentgenol and Rad Ther, 7, 355, 1920
ORNDOFF, B H, FARRELL, J I, and IVY, A C. Studies on Effect of Roentgen Rays on Glandular Activity, I Effect of Roentgen Rays on External Pancreatic Secretion, Am Jour Roentgenol and Rad Ther, 16, 349, 1926
PASCHER, FRANCES, and KANEE, B Reactions of the Hemopoietic System to Agents Used in the Treatment of Dermatoses, Effects of Low Voltage Roentgen Ray Therapy Arch Dermat and Syph, 53, 1, 1946

PFAHLER G E and ZULICK J D The Treatment of Exophthalmic Goiter (Basedow's or Graves' Disease) by Means of the Roentgen Rays Am Jour Roentgenol and Rad Ther 3 63 1916

PHILIPP C Zur Aetiologie des acuten Gelenkrheumatismus Deutsch Arch f klin Med 76 150 1903 Abstr München med Wchnschr 50 1218 1903

———— Die Rontgenbestrahlung der Hoden des Mannes Fortschr a d Geb d Rontgenstrahlen 8 114 1904

POHLE E A Theoretical Principles of Roentgen Therapy Philadelphia Lea & Febiger 1938

POHLE E A and BUNTING C H Studies of the Effect of Roentgen Rays on the Liver Acta Radiol 13 117 1932

PUSEY W A and CALDWELL E W The Practical Application of Rontgen Rays in Therapeutics and Diagnosis Philadelphia W B Saunders Company 1903

REGAUD C NOGIER T and LACASSAGNE A Sur les effets redoubtables des irradiations étendues de l abdomen et sur les lésions du tube digestif déterminées par les rayons de Rontgen Arch d élect méd 21 321 1912

RUDBERG HANS Studien über die Thymusinvolution I Die Involution nach Rontgenbestrahlung Arch f Anat u Entwcklngsgesch Suppl Bd p 123 1907

SAREZKI Ueber die experimentelle Rontgen atrophie der Ovarien und ihre Folgen Abstr Fortschr a d Geb d Rontgenstrahlen 13 423 1908–1909

SENN N The Therapeutical Value of the Roentgen Ray in the Treatment of Pseudoleucaemia New York Med Jour 77 665 1903

SIEDAMGROTZKY KURT Ueber das verhalten der Hautkapillaren im rontgenbestrahlen Gebiet Strahlentherapie 19 84 1925 Abstr Am Jour Roentgenol and Rad Ther 14 485 1925

TATARSKY A Experimentelle untersuchungen über die Einwirkung der Rontgen strahlen auf tierisches Blut Zt chr f med Elektrol u Rontgenk 9 1 49 1907

TERBRÜGGEN A and HEINLEIN H Hypoglykamie nach experimenteller Roentgen bestrahlung des Pankreas Klin Wchnschr 11 1139 1932

THOMAS H E and BRUNER F H Chronic Radium Poisoning in Rats Am Jour Roentgenol 29 641 1933

TURNER C W and GOMEZ E T The Radiosensitivity of the Cells of the Mammary Gland Am Jour Radiol 36 79 1936

WARREN SHIELDS Effects of Radiation on Normal Tissues Arch Path 34 443 562 749 917 1070 1942 35 121 304 1943

WARREN S L and WHIPPLE G H Roentgen Ray Intoxication I Unit Dose Over Thorax Negative—over Abdomen Lethal Epithelium of Small Intestine Sensitive to X Rays Jour Exp Med 35 187 1922

———— Roentgen Ray Intoxication II A Study of the Sequence of Clinical Anatomical and Histological Changes Following a Unit Dose of X Rays Ibid p 203

———— Roentgen Ray Intoxication III Speed of Autolysis of Various Body Tissues After Lethal X Ray Exposure The Remarkable Disturbance in the Epithelium of the Small Intestine Ibid p 213

———— Roentgen Ray Intoxication I Bacterial Invasion of the Blood Stream as Influenced by X Ray Destruction of the Mucosal Epithelium of the Small Intestine Ibid 38 713 1923

CHAPTER XXI.

ACTION OF *X*-RAYS AND RADIUM ON PATHOLOGIC TISSUE.

For many years clinicians and scientists have endeavored to ascertain the reason for the biologic action of *x*-rays and radium. Much definite knowledge has resulted from this enormous research and voluminous literature. However, the problem still waits solution. Borak, for instance, believes that the principal action is on the vascular system, while Desjardins and most investigators are convinced that the basic or primary effect is on cells that are especially radiosensitive —leukocytes, young cells, etc.

In this chapter we present only a sketchy outline of the subject. For complete details and literature the reader is referred to articles and books by Desjardins, Ellinger, Pohle and Warren. We are indebted to these works for much of the information contained in this chapter. These references are in the bibliography at the end of the chapter.

The cytologic, biochemical and bacteriologic action of radiation has already been discussed. It now remains to apply this knowledge, speculatively, in an attempt to explain the action of *x*-rays and radium in disease The chief facts to be kept in mind are.

1 Each variety of cell has a specific range of sensitiveness to a given dose of rays.

2. Cells with a short life cycle or cells that divide at frequent intervals are much more sensitive than cells that have a long life cycle or that divide at long intervals or not at all. Thus leukocytes, especially lymphocytes, are the most radiosensitive and nerve cells the least sensitive of all cells

3 Undifferentiated, immature, biologically or physiologically active cells are most readily influenced by irradiation.

4 Cells are most sensitive when they approach or pass through the active phase of mitosis.

STIMULATION.

At one time much was heard of the so-called stimulating action of radiation on cells and tissues, and the favorable effect of exposure to *x*-rays or radium in certain diseases was often attributed to such action.

The idea that *x*-rays or radium can stimulate cells arose partly from the observation that in some conditions, such as eczema, psoriasis and especially mycosis fungoides, a small dose was often sufficient to exert

a beneficial effect, and partly from the attempt to apply to these radiations the Arndt-Schulz law, according to which small doses stimulate while large doses inhibit or destroy cellular activity. As for the first of these reasons, experiments on animals have long since made clear why certain pathologic processes are so amenable to irradiation. Now that the exceptional sensitiveness of leukocytes is well known, it is not difficult to understand why the lesions of mycosis fungoides are so profoundly and so rapidly influenced by the x-rays or radium. All lesions characterized by leukocytic infiltration should be susceptible to irradiation in proportion to the degree of infiltration, especially by lymphocytes. This has been amply substantiated by clinical radiotherapy as applied to many forms of acute inflammation. This is also true of chronic inflammations, but on them the action of the rays is less rapid, probably because leukocytic infiltration is usually less pronounced and because more or less prominent features of these lesions are proliferation of connective tissue, caseous degeneration or calcification. It is assumed that the destruction of leukocytes releases protective substances which become available for defensive purposes.

The Arndt-Schulz law was intended to apply to pharmacologic phenomena, but it has not been generally accepted even by the pharmacologists. The attempt to extend its application to radiologic and biologic phenomena has not been successful, and it is now in discredit.

Numerous experiments on animals, repeated over a long period of years, have established the fact that direct stimulation in the sense of prolonged or continued acceleration of cellular activity cannot be induced by exposure to x-rays or radium. When the dose of rays is sufficiently small, the cells are not perceptibly influenced. After a slightly larger dose a temporary increase in cellular division may be observed, but if the period of observation is long enough, the increase in cellular metabolism is invariably followed by a return to normal activity or by a decrease in cellular metabolism. After large doses an increase in cellular metabolism is seldom observed as a primary effect; the initial effect is almost always to inhibit mitosis and to induce cellular degeneration, the degree of which depends on the variety of cell, the dose of rays, and the intensity in unit of time with which the exposure may have been made. After a period of depressed cellular activity a sharp increase in mitosis may be noted; this is a compensatory phase and is followed by return to normal.

The majority of cutaneous diseases represent some form of acute or chronic inflammation and are characterized by varying degrees of leukocytic infiltration, cellular hyperplasia, hyperemia, and proliferation of connective tissue, with or without associated products of cellular degeneration. If stimulation in the usual sense were caused or favored by x-rays or radium, some of the foregoing features should increase after therapeutic irradiation. This can occur only after excessive exposure.

The so-called stimulating effect of x-rays and radium has also been held to account for the increased rate of growth of epitheliomas or sarcomas which sometimes is observed after irradiation There is little basis for such a notion. Even when a malignant tumor has never been exposed to x-rays or radium, its growth seldom proceeds at a steady rate. Changes in the vascular supply resulting from thrombosis or hemorrhage may be followed by a temporary check in the rate of growth, but later the cells in the same or in some other part of the tumor recover their rate of growth and, for a time, may actually grow at an increased rate This phenomenon is well known to physicians who have had an extended experience of malignant neoplasms Similar checking in the rate of cellular division and subsequent compensatory increase in the rate of growth may be observed after exposure to x-rays or radium, but this is only a temporary phase and should not be interpreted as a specific effect of irradiation

Adequate treatment of a neoplasm should be accompanied and followed by progressive destruction of its cellular elements and complete and permanent regression of the growth. When, because of insufficient dosage, improper arrangement of the scheme of treatment, or exceptional resistance of the tumor cells to irradiation, complete and permanent regression does not result, all that may be expected is a gradual renewal of malignant growth at the same general rate as before treatment. The fact that sometimes an epithelioma or sarcoma may continue to develop rapidly in spite of x-rays or radium merely means that the dose has been insufficient to arrest the growth of the malignant cells, that the time distribution of the dose has been improper, or that the tumor cells are resistant to irradiation.

In this connection it has been claimed that irradiation of lupus erythematosus and lupus vulgaris favors the evolution of epithelioma This may indeed be true if the dose has been excessive But there is no evidence that epithelioma in lupus tissue is more prevalent today than before the advent of x-rays and radium, except, of course, in cases in which the lupus is complicated by chronic radiodermatitis

Hypertrichosis following x-ray treatment of acne vulgaris has been described, the growth of hair being due, it was thought, to the stimulating effect of the rays on the hair follicles. While this is possible, it must be admitted that hypertrichosis does not follow x-ray treatment of other diseases that require the same technic. Furthermore, superfluous hair is seen subsequent to acne vulgaris in instances when x-rays have not been employed. There is as yet no corroborated evidence showing that x-rays are capable of increasing the growth of hair It has been stated that x-rays are beneficial in alopecia (Holzknecht, Kienbock) Within the past year we have had several cases of alopecia areata in which hair grew in the patches which had received an epilating dose of 300 r unfiltered. The hair began to grow in about six weeks and was luxuriant Hair did not grow in the untreated bald areas of the same patient. Alopecia areata is capricious. We have

seen hair grow in one patch and not in others subsequent to various therapeutic methods and also spontaneously The phenomenon is being investigated and results will be reported later At present we can not say that x-rays are capable of making hair grow and later, if it can be proved that they can under certain conditions cause a growth of hair, we are confident that an explanation other than stimulation in the accepted sense, will be discovered

ANEMIA AND CONGESTION

Tissue that is ischemic tolerates radiation considerably more than tissue possessed of normal circulation Schwarz dehematized the skin by means of an elastic band and found that an area under the band tolerated a larger dose than the skin not covered by the band Schmidt by employing compression, was able to administer two erythema doses without reaction After trying inconclusive experiments with epinephrin, MacKee completely dehematized an entire forearm with an Esmarch bandage While the forearm was bloodless, a small area of skin was exposed to an erythema dose of x rays The circulation was then restored and an adjacent area was exposed to the same quantity The patient was seen two weeks after the experiment, at which time there was an erythematous reaction in both areas the reaction in the dehematized area being distinctly less intense than that of the normal area Three weeks later, the erythema in the dehematized area had disappeared while that of the normal area was still present

It is a common occurrence, when administering large doses to small congested lesions for the surrounding normal skin to react less vigorously than the congested lesions This may be due in part to the fact that the periphery receives a little less radiation than does the center of the treated area Again, even in congested lesions, if there happens to be considerable acanthosis and parakeratosis the normal skin may react more vigorously than does the lesion However, clinical and experimental evidence justifies the statement that congestion or hyperemia tends to increase radiosensitiveness while ischemia increases the tolerance of the tissues to some extent The difference is supposed to be due to the secondary rays from the iron contained in the erythrocytes

Of interest in this connection are the findings of Giraud and Pares They found that the decrease in the number of leukocytes and the other features of the hemoclastic crisis which occurs after intensive irradiation are due to the reaction of the tissues directly irradiated The hemoclastic crisis did not occur when the part irradiated was shut off from the general circulation It developed, however when the obstruction to the circulation was removed even after the x-rays had been shut off The explanation is that the substances producing the shock manifested by the hemoclastic crisis are evidently generated

in the irradiated area. There is thus a kind of indirect autoprotein therapy which may supplement the beneficial influence of the rays

ACCUMULATION.

The effect of repeated irradiation is cumulative and accumulation results in inhibition. The degree of accumulation depends on the size of the dose and the interval between treatments. As was shown in other chapters, Kingery and others have placed this question on scientific grounds.

BACTERIA.

In Chapter XIX it was shown that gamma rays and x-rays in therapeutic doses do not exert any appreciable influence on the growth of bacteria in culture. The occasional quick response to roentgenization of bacterial diseases, such as sycosis vulgaris, acne vulgaris and acne varioliformis, has suggested the possibility of a direct or indirect effect on the causative microorganisms Positive cultures in bacterial and fungus diseases have been obtained repeatedly for days and even weeks subsequent to irradiation.

A better explanation for the efficacy of x-rays or radium in many bacterial inflammations, in favor of which impressive experimental and clinical evidence can be presented, relates to the radiosensitiveness of leukocytes It is well known that leukocytic infiltration (lymphocytes and polymorphonuclear leukocytes) is an early and important step in the cellular defense against infection of any kind. In view of the sensitiveness of the varieties of leukocytes mentioned, and in view of the repeated observation that the greater the proportion of infiltrating leukocytes the more rapid and the more pronounced is the response of inflammatory lesions to irradiation, it seems more than likely that the main feature of the action of the rays is to destroy a proportion of the infiltrating cells. The immediate consequence is that the antibodies, ferments and other protective substances elaborated within these cells are liberated and made more readily available for defensive purposes. Another effect established by numerous experiments is a secondary increase in phagocytosis. It is well known also that in acute lesions a single, small dose is usually sufficient, while in chronic lesions, especially those of a tuberculous character, larger doses must be repeated at intervals for some time. This difference may be due to the known difference in the degree of leukocytic infiltration on the one hand and, on the other, to the presence in chronic lesions of varying degrees of proliferating connective tissue which, being much less radiosensitive than leukocytes, tends to retard the favorable influence of the rays.

There is no evidence to support the idea that x-ray or radium treatment can directly sterilize bacterial diseases But the favorable result often seen in such definite staphylococcic diseases as furunculosis (localized) and sycosis vulgaris and erysipelas (streptococcus),

indicates that irradiation can and frequently does have a favorable influence on processes caused by bacterial invasion Many of the bacterial diseases that are amenable to irradiation are follicular in type, and another possible factor in the efficacy of irradiation lies in the fact that the hair follicles are radiosensitive Acne varioliformis (probably staphylococcic) and acne vulgaris (supposedly due to the acne bacillus and the staphylococcus) respond favorably Cutaneous tuberculosis yields slowly The cutaneous lesions of syphilis and leprosy may improve under roentgenization but not to a useful degree The common wart, caused by a virus often undergoes involution as a result of a single erythema dose Conversely, the flat juvenile wart and other forms of verruca also caused by a virus, are recalcitrant Eczema caused by fungi is often more stubborn than other forms of eczema It is well known that an incomplete depilation often suffices to cure tinea tonsurans This might be accepted as indicating a parasiticidal action, but a more reasonable interpretation is that the affected hairs depilate more readily than do the healthy hairs

In concluding this phase of the subject, it is sufficient to say that there is no experimental proof and very little clinical evidence to support the sterilization theory as applied to microorganisms It is possible that in some instances irradiation might increase resistance against the invading organism through some biochemical alteration The most plausible hypothesis, based on substantial evidence is that the rays act directly on the infiltrating leukocytes and on the sensitive cells of cutaneous appendages and that the effect on the bacteria is indirect

INHIBITION

In the light of present knowledge the effects of radiation can be best explained, perhaps, by an inhibitory action on karyokinesis, on young cells undifferentiated cells and cells that are physiologically very active by destruction of leukocytes and the effect on the vascular system Most of the cutaneous diseases that are amenable to irradiation regardless of the cause are associated with hyperemia and multiplication of tissue elements or overactivity of secreting epithelium resulting from cellular hyperplasia

NEVI AND CONGENITAL ANOMALIES

In the hyperkeratotic group, that is in cases of ichthyosis verrucous nevus and keratoderma palmaris et plantaris a congenital anomaly interferes with the process of normal keratinization The result is a thickened horny layer which exfoliates after irradiation It is possible that the temporary relief is due to mitotic retardation in the basal cell layer although there may be also a direct influence on the process of keratinization As soon as inhibition ceases abnormal keratinization continues

Vascular Nevi.—The elevated types of nevus vasculosus yield to radium in a striking manner. Even the cavernous nevus disappears under safe therapeutic dosage. It seems paradoxical, but the superficial port-wine mark is exceedingly stubborn. The types that respond well begin after birth and continue to increase in size for weeks and months. There is a numerical increase in the blood vessels which are dilated, abnormally cellular, and continue to develop by budding processes; in other words, a new growth in which the cells are more or less embryonic in type. When exposed to x-rays or radium it is probable that mitosis is arrested, new vessels cease to form and finally the poorly differentiated cells composing the vessels fail to be replaced and are absorbed. The troublesome port-wine mark is fully developed at birth; the cells are mature, well differentiated and not very active. It is probably for these reasons that lesions of this type are not amenable to irradiation. The effect can, perhaps, be likened to telangiectasia. *To cause an obliterating endarteritis in telangiectasia, spider nevus and port-wine mark, requires an amount of treatment that will seriously injure normal tissue.* The explanation of the effect or lack of effect of irradiation on lymphangioma is presumably the same as on angioma.

DISEASES DUE TO LOCAL CAUSES.

Of the many dermatoses falling under this heading, with the exception of eczema of external origin and the bacterial diseases, only two characterized by pathologic hypertrophy are treated with x-rays and radium. These are corns and calluses (cornu, callositas). These lesions are characterized by acanthosis and particularly hyperkeratosis, a protective reaction to traumatism. The increased activity presumably is in the lower part of the rete and in the basal-cell layer. Irradiation prevents further multiplication of cells and the horny layer exfoliates. If, in the meantime, the local cause has been removed, there may be no further development.

It is difficult to comprehend the reason for the difference in the behavior of the various types of verrucæ, all of which are of virus origin, when irradiated. The common plantar wart is fairly susceptible. So, also, is verruca vulgaris. Verruca plana, verruca filiformis, verruca acuminata and the mosaic type of plantar wart are less susceptible. Senile and seborrheic keratoses, which are of unknown etiology, appear to be less susceptible than verruca vulgaris. *The difference may be a question of virulence and adaptability, or of the rate of cellular hyperplasia.* In cases of multiple common warts, irradiation of one wart or even of a lesion of another disease may be followed by a disappearance of all the warts (Delbanco, Halberstaedter and others). This has been thought to indicate the formation of antibodies or autogenous vaccines, but the same phenomenon has been

observed in connection with other forms of treatment and it must not be forgotten that warts may disappear spontaneously or as a result of suggestion

ECZEMA AND OTHER INFLAMMATIONS

The effect of radiation on eczema may be complex but inhibition of cellular hyperplasia and the effect of the rays on infiltrating leukocytes and the vascular system may be sufficient to explain the favorable effect of irradiation In the early stage of acute dermatitis when the objective symptoms consist of erythema and edema irradiation appears to have very little effect Even in vesicular dermatitis if the vesiculation occurs before hyperplasia of the epidermis treatment does not abort the eruption although further development may be prevented After the leukocytic infiltration and especially acanthosis has been established irradiation is very effective, presumably by destroying infiltrating leukocytes and curbing mitosis of hyperplastic cells

In the squamous form of eczema the process is partly as outlined in the foregoing description, but hyperkeratosis and parakeratosis are more definite and the infiltration contains distinctly more fixed connective tissue cells It might be argued that both the epidermal hyperplasia and the infiltration are protective and that inhibition of mitosis should be injurious instead of beneficial In many inflammations, eczema included, the epidermal response is exaggerated and, while at first it may be protective, the later overgrowth is due to an excess of nutrition It is the overgrowth that radium and x rays tend to prevent As for the infiltration, irradiation restricts the formation of new cells *in situ*, but there is little if any effect on migratory cells from the blood stream The local lesions of eczema are self limited they represent a reaction to an irritant and, when the irritant is removed the lesions disappear spontaneously Irradiation, while promoting the resolution of individual lesions, does not seem to influence the causal factor or the disease Unfortunately, this is true of many of the dermatoses

Accepting eczema as a pattern for the inflammations, the same explanations hold for diseases such as psoriasis and lichen planus As pointed out by Highman and Rulison, the psoriatic scale is composed of hyperkeratotic and parakeratotic tissue There are numerous mitoses The infiltration consists mainly of small round cells of the lymphatic type, with a variable number of fibroblasts The object of x-ray treatment is to inhibit epidermal hyperplasia and promote resorption of the inflammatory deposit The rationale of this is a direct attack on the multiplying cells of the rete and small round cells in the infiltration which probably by analogy with lymphocytes are vulnerable to the rays

The epidermal changes in lichen planus are less pronounced than in lichenification, but the infiltrations in the two conditions are equally voluminous. The infiltrating cells in lichen planus resemble lymphocytes, mixed with melanoblasts. The latter cells remain long after the papules have resolved, and they are not affected by further roentgenization

Eczema and psoriasis occasionally become dermatitis exfoliativa, a condition likely to offer considerably more resistance than do its predecessors, even in instances in which the morphology is much the same. It not infrequently happens that the first few attacks of psoriasis disappear promptly under the influence of *x*-rays while later attacks may be irresponsive. The same phenomenon is observed in cases of mycosis fungoides, leukemia cutis, Hodgkin's disease, epithelioma, sarcoma and rarely in other diseases. In the case of virus diseases increased virulence of virus or increased susceptibility to virus may be factors. Doubtful possibility of acquired resistance to irradiation should also be considered

In the erythema and urticaria groups, the *x*-rays are not employed However, prurigo, which is thought by some authorities to be a papular urticaria, at times responds well to fractional treatment, but recurrence is the rule The lesions consist of round-cell infiltration, below an epidermis which is slightly vesicular.

When treating generalized dermatoses, especially diseases that are very radiosensitive, such as mycosis fungoides, particularly if large surfaces are exposed to fairly large amounts of radiation, a febrile reaction may develop together with a more or less generalized toxic rash, and the original eruption may become more manifest.

DISEASES DUE TO BACTERIA.

Sycosis vulgaris was mentioned under Bacteria at the beginning of this chapter. In many cases of pyogenic sycosis the disease cannot be eradicated until permanent alopecia has been produced It is easy to understand the mechanism of cure in such instances Sometimes, a cure is obtained without even a temporary loss of hair; this probably results from the action of the rays on the leukocytic infiltration

Acne Vulgaris.—The pathologic changes in cases of acne vulgaris consist of a preliminary inflammation of the distal third of the hair follicle and of the sebaceous duct and gland This inflammation is supposedly due to the acne bacillus and results in hyperplasia and exfoliation of the follicular epithelium together with overactivity of the sebaceous glands Exfoliation is largely responsible for the comedo, the pustule is thought to be due to the staphylococcus. Inhibition of cellular division and sebaceous secretion, the action on infiltrating leukocytes, and the indirect action on bacteria are the probable functions of irradiation in this disease.

Tuberculosis and Other Granulomas —Cutaneous tuberculosis belongs pathologically to the granulomas and, as the discussion concerns the granulomas rather than tuberculosis, it will include bacterial diseases such as leprosy, syphilis, rhinoscleroma, and fungus diseases such as blastomycosis and actinomycosis and, as representatives of the non-bacterial granulomas, mycosis fungoides, leukemia cutis and granuloma annulare Mycosis fungoides and the entire lymphoid group of diseases—leukemia cutis, lymphogranulomatosis cutis, reticuloendotheliosis Hodgkin s disease, etc , respond favorably as a rule, although only temporarily, to irradiation The probable reason for this high degree of radiosensitiveness is the fact that the entire reticuloendothelial system is profoundly affected by both *x*-rays and radium The lesions of granuloma annulare usually undergo complete involution as a result of a single erythema dose The non-bacterial granulomas are the most susceptible members of this group The fungus diseases can be accorded second place as both actinomycosis and blastomycosis yield, as a rule to comparatively small doses

The lesions of syphilis and leprosy may yield to a certain extent The more benign types of cutaneous tuberculosis, sarcoid and erythema induratum, also are susceptible The inactive atrophic type of lupus vulgaris with deeply imbedded apple-jelly nodules is particularly unyielding The comparatively active hypertrophic lupus ulcerated lupus and tuberculosis verrucosa cutis are more susceptible and the very active miliary lupus and tuberculosis orificialis are likely to be even more susceptible With the exception of syphilis, it will be noted that susceptibility bears some relation to duration and activity The rapidly developing granulomas, actinomycosis, blastomycosis, granuloma annulare and miliary lupus, involute more rapidly under irradiation than do those of slow evolution, that is, lupus vulgaris and rhinoscleroma It is significant that the most inactive granuloma, barring leprosy, is the most resistant namely, atrophic lupus vulgaris Such observations support the view that the principal effect of the rays on the various lesions mentioned is closely related to the degree of leukocytic infiltration the rate of cellular hyperplasia, the known sensitiveness of lymphocytes and the degree of proliferation of connective tissue

DISEASES OF THE APPENDAGES

All of the appendages, with the exception of the nails, and especially the hair follicles are quite radiosensitive The comparative immunity of the nails may be due in part to filtration The relative susceptibility of the hair follicles is perhaps caused by the rapid division of cells and the large number of young cells always present at or near the bulb The action on the coil and sebaceous glands is presumably a retardation of physiologic activity Permanent results in hyperhidrosis and seborrhea are due to atrophy of the coil and sebaceous glands This may be due to a direct effect on the epithelium or to a lessened blood

supply caused by sclerosis and contraction of the connective-tissue stroma. Many fungus and bacterial diseases of the hair follicles cannot be cured by roentgenization without a defluvium. This is always so in tinea tonsurans and favus and very frequently in sycosis vulgaris, folliculitis decalvans, etc. In such instances irradiation acts as a depilatory, the microorganisms being removed with the hair.

PRURITUS.

It has been stated repeatedly in the literature that x-rays relieve pain. This is true when painful lesions resolve as a result of irradiation. Occasionally, applications of x-rays or radium appear to relieve pain due to inflammation of a nerve—neuritis Occasionally, also, intensive treatment may be followed by pain that may last several weeks, the pain occurs in conjunction with ulcerative dermatitis resulting from excessive doses of insufficiently filtered x-rays or radium, and is due to secondary infection, or vascular changes, or both Such observations have led certain writers to attribute the analgesic effect of irradiation to a direct action of the rays on the nerves. In view of the great resistance of nerve cells to irradiation, this assumption seemingly has little foundation. It is more probable that relief from pain results from a release of the affected nerve from pressure or irritation caused by adjacent inflammatory or malignant deposits The rays act directly on the lesion and relief from pain is an indirect effect That x-rays and radium frequently allay severe itching is an accepted fact When the pruritus is due to a cutaneous eruption, its disappearance usually coincides with the involution of the eruption It is difficult to explain why irradiation should overcome the symptoms of a disease such as pruritus ani. The effect is certainly not always psychologic. If it can be assumed that itching, in cases of pruritus without visible cutaneous changes and which are amenable to roentgenization, is due to alterations in the collagen or in the sensory terminals or fibrils (inflammation), it is conceivable that radiation may act by inhibiting proliferation of cells and chemical action.

NEW GROWTHS.

The sensitiveness of tumor cells to x-rays and radium corresponds closely to that of the normal parent cells from which the tumor cells are derived Thus, tumors of lymphoid structures, made up chiefly of lymphocytes, are most sensitive, and growths made up of nerve cells are least sensitive to irradiation Tumors composed of other varieties of cells fall between these two extremes. The basal-cell epithelioma is much more susceptible than the squamous-cell epithelioma, but the former is much less vulnerable than lymphoid tumors grouped under the designation of "lymphoblastoma." Cutaneous fibroma, myoma, and neuroma hardly respond at all The benign

epithelial new growths—syringoma, trichoepithelioma, multiple benign cystic epithelioma, etc —are very stubborn The same differences are noted in the sarcoma group Benign endotheliomas are radioinsensitive Lymphosarcomas respond well to irradiation, as does Kaposi sarcoma Spindle-cell and round-cell sarcomas are much less radiosensitive The difference in susceptibility seems to be largely one of cytology and morphology The benign epitheliomas are quiescent lesions probably nevoid in character The cells are mature differentiated and are not undergoing rapid division The basal cell epithelioma is composed of cells that are constantly, although not rapidly, multiplying The cells are derived from the stratum germinativum and show no tendency to produce keratohyaline In other words, they are immature and unspecialized, the type of cell that one might expect to see influenced by irradiation Cutaneous prickle cell or squamous-cell cancer is composed of cells that are undergoing rapid division but the cells, for the most part, are less embryonic in type than those of basal cell epitheliomas, and presumably for this reason more resistant

As is well known, Broders divides squamous-cell epithelioma into four grades based upon cell differentiation Grade one contains from 75 to 100 per cent differentiated cells It is the least malignant and the least radiosensitive of the four grades Grade four, the most malignant and the most radiosensitive, contains from 75 to 100 per cent undifferentiated cells Between the very susceptible basal cell epithelioma and the less susceptible squamous cell neoplasm, is the baso-squamous-cell epithelioma which is derived from both the basal-cell layer and the prickle-cell layers of the epidermis There is considerably more leukocytic infiltration, as a rule, associated with basal cell growths than with prickle-cell tumors In addition to the action of radiation on the epithelial cells, some investigators believe that the destruction of leukocytes with liberation of protective substances may be one reason for the greater susceptibility to irradiation of the basal cell tumors

Connective tissue growths and hyperplasias are radioresistant unless composed of young rapidly evolving cells as in the case of young keloids Old, hard keloids and hypertrophic scars are more radioresistant

The Malignant Cell and the Lethal Dose —There has been and there still is considerable difference of opinion as to which method has the most effect on the malignant cell with minimal injury to the skin and other normal structures—a single lethal dose or fractionated irradiation Another controversy is related to wave lengths It now appears to be the consensus that the wave length is of importance only in regard to having a maximum amount of radiation reach the malignant cell It has been shown by Wood and Prime, and many others, that a cell at the surface can be destroyed with x-rays of almost any wave

length. In order to reach the malignant cells in clinical work filtration and moderately high voltage are necessary.

For many years the single dose technic was employed by most radiologists. Wood and Prime determined, experimentally, the lethal dose as follows:

"Approximately 4 erythema doses of x-rays, given continuously, are required to kill mouse carcinoma and 5 such doses to kill mouse sarcoma when exposed *in vitro*, but occasionally some cells may escape the effects of even 6 doses

"Approximately 6 erythema doses of x-rays are required to kill sarcoma cells *in vivo* as compared with 5 doses required to kill the same cells *in vitro*, and approximately 6 erythema doses are required to kill carcinoma cells *in vivo* as compared with 4 doses required to kill the same cells *in vitro*"

In practical work it is well known that from 6 to 12 or even more erythema doses, given at one time, are necessary to destroy carcinoma at or near the surface, depending upon the size of the lesion and the type of cell.

As discussed elsewhere, the fractionated technic is now employed by most radiologists This consists of administering daily erythema or suberythema doses for from five to twenty days, the total ranging from one thousand to several thousand roentgens With such method it is claimed, and it appears to be the consensus, that it is possible to administer a lethal dose with much less injury to normal structures than with a large single dose; also that the cells are kept "saturated" for a long period, which prevents mitosis As stated in greater detail elsewhere, the method embraces the time-intensity factor, "recovery," "saturation," etc., in addition to quantity and quality.

ACQUIRED RESISTANCE

Lesions of mycosis fungoides which at first are exceedingly susceptible to irradiation finally cease to respond even to large doses. To some extent this is true of the entire group of leukemic diseases It is possible that this is due to the gradual evolution of the disease, to the sapping of general resistance, and to the progressive exhaustion of the blood-forming structures, rather than any increase in specific cellular resistance to irradiation. The same phenomenon has been observed in epithelioma. Occasionally, too, psoriasis and other diseases behave in the same manner.

BIBLIOGRAPHY

Borak, J Radiation Effects on Blood Vessels, Radiology, 38, 481, 607, 718, 1942.

Broders, A C The Grading of Carcinoma, Minnesota Med , 8, 726, 1925

Delbanco, Ernest Verschwinden der Warzen beider Hände nach Röntgenbestrahlung einer Hand, Dermat Wchnschr , 55, 1524, 1912

Desjardins, A U Action of Roentgen Rays or Radium on Inflammatory Processes, Radiology, 29, 436, 1937

Desjardins A U Radiosensitiveness of Cells and Tissues Arch Surg 25 926 1932
——— Dosage and Method of Roentgen Therapy for Inflammatory Conditions Radiology 32 (9) 1939
——— Radiotherapy for Inflammatory Condition Jour Am Med Assn 116 ... 1941
Ellinger F The Biologic Fundamentals of Radiation Therapy New York Elsevier Publishing Co Nordeman Publishing Co Distributors 1941
Girald Marthe Girald Gaston and Parès L De la crise hémoclasique des irradiations intensives Pre e méd 30 85 1922
Halberstaedter I Verschwinden samtlicher Warzen nach Rontgenbehandlung einer kleinen Anzahl derselben Dermat Wchnschr 55 1572 1912
Highman W J and Rulison R H Expectancy in Roentgen Ray Treatment of Skin Lesions from the Pathologic Standpoint Arch Dermat and Syph 6 413 1922
Holzknecht Guido Roentgen therapy as Practiced in the Roentgen Laboratory of the Allgemeine Krankenhaus of Vienna Arch Roentgen Ray 9 262 292 1905
——— Gibt es eine Reizwirkung der Rontgenstrahlen? Munchen med Wchnschr 70 761 1923
Kienbock Robert On the Radio-therapeutic Treatment of Diseases of the Hair Arch Roentgen Ray 12 12 1907–1908
Kingery I B Saturation in Roentgen Therapy Its Estimation and Maintenance Preliminary Report Arch Dermat and Syph 1 423 1920
Kok Friedrich Weitere tierexperimentelle Studien uber die Wirkung der Rontgenstrahlen auf das Karzinom Deut ch med Wchn chr 50 298 1924
Pohle E A Theoretical Principles of Roentgen Therapy Philadelphia Lea & Febiger 1938
Schmidt H E Eine Vorrichtung zur Desensibilisierung der Haut bei Tiefenbestrahlungen Fortschr a d Geb d Rontgenstrahlen 15 117 1910
Schwarz Gottwald Ueber Desensibilisierung gegen Rontgen und Radiumstrahlen Munchen med Wchn chr 56 1217 1909
Warren Shields Effects of Radiation on Normal Tissues Arch Path 34 443 562 749 917 1070 1942 35 121 304 1943
Wood F C The Results of the Experimental Study of Cancer Editorial Am Jour Roentgenol and Rad Ther 11 188 1924
——— Further Studies in the Effectiveness of Different Wave Lengths of Radiation Radiology 5 199 1925
Wood F C and Prime Frederick Jr The Action of Radium on Transplanted Tumors of Animals Ann Surg 62 751 1915
——— Lethal Dose of Roentgen Rays for Cancer Cells Jour Am Med Assn 74 308 1920

CHAPTER XXII.

CLINICAL EFFECT OF ROENTGEN RAYS AND RADIUM RAYS ON THE SKIN

RADIODERMATITIS.[1]

THE term radiodermatitis is an old one dating back perhaps to about 1900. It was coined to indicate a cutaneous inflammation caused by *x*-rays which, at that time, was the only type of *x*-ray reaction known. Since the advent of filtered radiation, especially heavily filtered, exceedingly high voltage radiation, *x*-ray reactions and injuries have been observed in which the skin is not involved or in which the cutaneous inflammation is of minor importance In this category may be mentioned injuries to viscera and other deep tissues in which the skin is unaffected because of multiple portals (cross fire); or when the injury to the subcutaneous tissue equals or exceeds that of the skin, as when radium or radon is applied to deep structures by means of needles or implants. In addition, there are the sequelæ of irradiation such as atrophy, pigmentation, depigmentation, telangiectasia, keratoses and cancer; and finally, the so-called radiation sickness. Obviously, the term radiodermatitis cannot include all these reactions and injuries, although for many years it was used to designate most of them. It is now customary to restrict the term radiodermatitis to cutaneous reactions and injuries. These reactions and injuries may occur in the skin or orificial mucous membranes. They may be mild and last only a few weeks, or they may be severe and endure for months or years, or they may be permanent. They may consist of some of the sequelæ mentioned above. All other untoward effects resulting from the application of *x*-rays to human tissue are usually called *x*-ray reactions and injuries. On the whole, it is perhaps preferable to speak of reactions and injuries rather than of radiodermatitis Some writers include under the term radiodermatitis cutaneous reactions caused by radium, while others use the term radium dermatitis. Vernacular terms used as synonyms for radiodermatitis are: *x*-ray dermatitis, *x*-ray reaction, roentgen-ray dermatitis, roentgen dermatitis, roentgen-ray reaction, roentgen reaction, roentgen-ray "burn," and *x*-ray "burn"

Latent Period.—After a single erythema dose of *x*-rays or radium the first clinical manifestation of a reaction is seen usually about the end of the first week. In some instances the reaction is observed within the first twenty-four hours, then it subsides and reappears about the fifth

[1] Robbins *et al* reported in Radiology 46, 1, (Jan) 1946, cases of accidental burns of skin and eyes caused by scattered cathode rays

day. Thus there is an interval of several days of clinical inactivity. This period of latency is variable in regard to duration as will be shown later in this chapter. Also, it is a period of considerable histologic activity (see Chapter XXIII).

PSEUDO X-RAY REACTION

"Electric" Erythema

Occasionally one encounters an erythematous reaction an hour or two after irradiation especially when the irradiated area is surrounded by lead foil. The hyperemia endures a day or two and disappears without leaving pigmentation or other x-ray sequelae. It may be accompanied by such subjective symptoms as burning, stinging and itching. Also there may be associated edema and if the treatment happens to include the parotid glands there may be a swelling of these glands. These early, temporary, and harmless reactions not infrequently occasion considerable alarm not on account of the symptoms but because of the knowledge that true x-ray reactions of the third degree begin very soon after irradiation. Pfahler believes that they are caused by an electrostatic discharge and that they can be prevented by grounding the lead foil that is placed around the irradiated area for the purpose of protection. Most roentgenologists agree with Pfahler. The phenomenon was noted by Schultz, Beclère and others years ago.

CUTANEOUS X-RAY AND RADIUM REACTIONS

Radiodermatitis of the usual variety may be divided into two types—acute and chronic. The acute type is subdivided into three degrees, namely, first, second and third degrees.

First Degree.—The first-degree reaction consists of a simple cutaneous erythema or hyperemia. This may vary from a hardly perceptible flush to one that is intensely red and associated with slight edematous swelling. The subjective symptom is burning or tingling; there may be itching. The reaction becomes manifest, as a rule, in from five to seven days and reaches a maximum of development in from ten to fourteen days, after which the bright red color changes gradually to a dull red, then to a brownish red and disappears usually in the third or the fourth week. Pigmentation may remain for several weeks and there is likely to be some desquamation during the stage of involution. If the affected area involves a hairy part, depilation is apt to occur during the third week. The alopecia may be temporary or permanent.

Second Degree.—There is no sharp line of demarcation between reactions of the first and second degrees. It is generally understood that if a reaction progresses beyond hyperemia and slight edema it is of the second degree. A second-degree reaction is recognized by

edema, vesiculation, erosion or superficial ulceration. The erythema of second-degree reactions is likely to develop two or three days earlier than that of the first degree In a few days the color is scarlet,

FIG. 68 —First-degree radiodermatitis Area on arm shows a moderate reaction while the area on the forearm shows a more intense reaction

it then becomes purplish red or bluish red—livid In ten days or two weeks the intense cutaneous edema destroys all or part of the

FIG 69 —Second-degree reaction of mild type Here there is edema with some vesiculation, erosion and exudation

epidermis, with a consequent moist or exudative, eroded surface This development may or may not be preceded by vesicle formation. The exudate drys into a crust which may be impetiginous, but which

may be firm and dry The subjective sensation is first tingling and burning and then a burning pain which may be distressing Second-degree reactions will heal spontaneously in from six weeks to three months, depending upon the intensity of injury and the extent of surface involved Hair in the irradiated area will fall out in three weeks and the resulting alopecia will be permanent The regeneration of epidermis is complete and if the connective tissue has not been badly damaged and sequelæ do not develop the final result is clinically normal skin

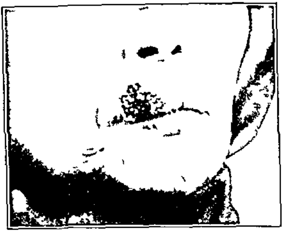


Fig 70 —Second degree radiodermatitis of severe type There is destruction of the epidermis with exudation and crusting and severe pain Reaction required about two months to disappear

Third Degree —There is no line of demarcation between reactions of the second and third degrees It may be said that if the ulceration or necrosis involves the true skin the reaction is one of the third degree The first evidence of reaction (erythema) is likely to be seen within twenty four or forty eight hours and in a few days it becomes of the livid or bluish red type In two or three weeks the congestion and edema of the deep tissues become intense even to the extent of board like hardness on palpation, the epidermis exfoliates leaving a denuded derma One of two things may now happen The injured cutis and subcutaneous tissue may undergo rapid ulceration or the affected parts may form a dry hard, necrosed mass with a crusted surface—dry gangrene (called fourth degree by some) In the latter instance the necrosed mass, surrounded by intense inflammation, will remain apparently stationary for weeks or months eventually it is converted into a slough which is finally thrown off the result being a deep ulcer In either instance after a period of considerable ulcerative activity assuming that the injury is beyond immediate repair, the ulcer develops distinctive characteristics The abrupt margins and the deep seated floor produce a punched-out appearance The absence of granulation tissue and the subsidence of reactive inflammation creates a dry glistening floor In other words, there is an indolent

ulcer. This is the usual clinical picture. There may be unhealthy granulations and a heavy muco-purulent discharge. The detailed

FIG. 71.—A typical third-degree, indolent, *x*-ray ulcer. Note the abrupt margin, the shiny dry base and the absence of granulation tissue. This ulcer required nearly two years to heal and the patient suffered excruciating pain for the first eight months.

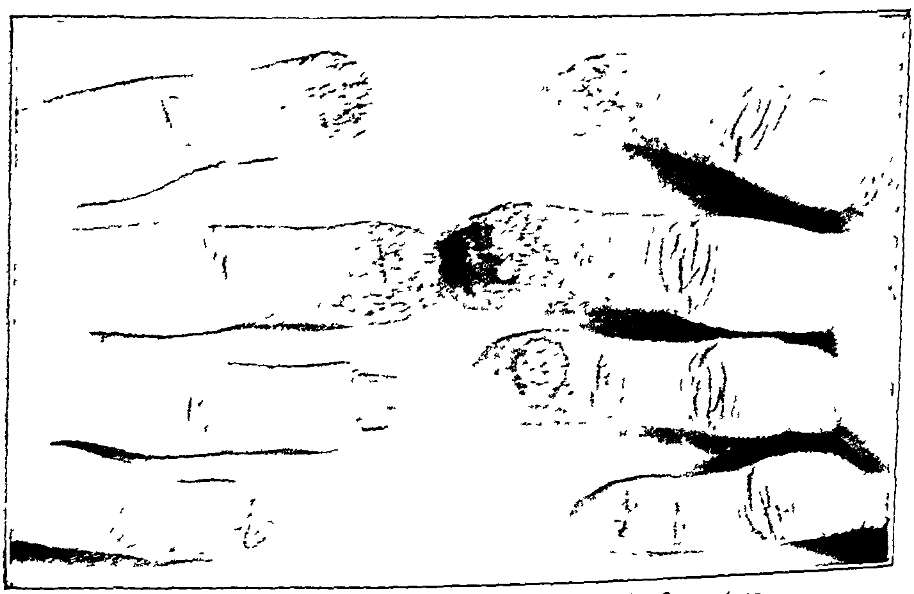


FIG. 72.—Third-degree radiodermatitis of the finger tips.

clinical picture will naturally vary with the degree of injury and the successful or abortive attempts at repair, together with the action of

bacteria The ulcer may involve part or all of the true skin, the subcutaneous tissue and even the muscles Small, comparatively superficial ulcers may begin to granulate in a month or two healing being complete in a few months The larger and deeper ulcers usually remain indolent for many months even years There may be on the other hand slow but steady healing and occasionally an ulcer of long standing will suddenly begin to granulate and heal rather promptly, As a rule however, if an ulcer has not undergone spontaneous repair within a year or eighteen months it will persist indefinitely

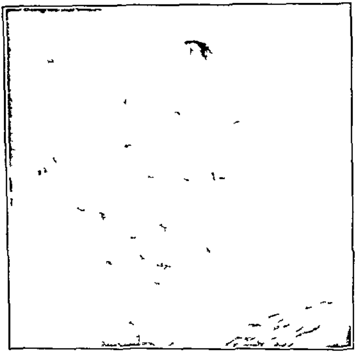


FIG 73 —Follicular radiodermatitis of a mild second degree

The cicatrix following a third degree ulcer may be healthy pliable and possess the color and palpable consistence of normal skin—in other words, of exceedingly good cosmetic quality The end results, unfortunately are likely to be marred by undesirable disfiguring and even dangerous sequelae These possible sequelae do not, however include cicatricial contractions and ectropion and it is very uncommon to see hypertrophic scars keloids or keloidal bands

The chief subjective symptom of a third-degree reaction is excruciating pain of a burning character The pain usually subsides just before healing begins Indolent ulcers remain exceedingly sensitive indefinitely, but the individual does not actually suffer after six, eight or twelve months

Unusual Features—We have encountered two instances of what might be termed follicular radiodermatitis (radiodermatitis folliculata) In both instances there was a moderate, diffuse erythema with slight

desquamation, over a circular area 6 inches in diameter. The follicular orifices and the perifollicular regions were slightly elevated and of a much more intense red color than that of the interfollicular portions of the affected area. In one of the patients there was a follicular atrophy following the disappearance of the eruption. The appearance was not unlike that seen on the extensor surface of the arms in adults who have the atrophic remains of a former keratosis pilaris.

Occasionally, in reactions of second and third degrees and even those of the first degree, there is considerable deep-seated edema of the unexposed adjacent tissue. This is especially likely to occur if the radiodermatitis is in the vicinity of the eyelids.

Variations in the period of clinical latency are not uncommon We have seen erythema develop within two or three hours after a radium application and persist for two or three weeks. In one such instance the involved areas showed telangiectasia after the lapse of over a year In another instance the erythema was followed by persistent pigmentation. First-degree *x*-ray reactions are manifested, at times, within twenty-four or forty-eight hours Conversely, the appearance of both mild and severe reactions may be delayed several days.

Complications.—Probably the most common and most annoying complication of exudative or ulcerative radiodermatitis is infectious eczematoid dermatitis. This disease originally described by Engman and later by Fordyce, appears to be a sensitization on the part of the skin to discharges from wounds, ulcers, sinuses, etc. Whether the sensitization is in relation to bacterial products or to other chemical ingredients in the discharge is unknown The first objective indications of complicated radiodermatitis are a redness and swelling with itching and burning or stinging beyond the confines of the previous inflammation. The dermatitis, unless checked, soon becomes exudative and spreads by peripheral extension and may become generalized

A number of instances of vegetations occurring in the course of acute radiodermatitis of the second degree have been observed. The lesions developed just previous to the first signs of repair They ranged in size from a lentil to a bean, were firm but not hard in consistence, yellowish red in color, and presented a moist surface They resembled the flat condyloma of syphilis It is possible that the lesions consisted of an overgrowth of unhealthy granulations and this hypothesis is probable because of their spontaneous disappearance in two or three weeks They possessed the clinical appearance of a proliferated epidermis (acanthosis) which, if true, would assume a proliferative type of acute radiodermatitis Granuloma pyogenicum must also be considered in these cases

Sequelæ.—The sequelæ of radiodermatitis and radium dermatitis are, unfortunately, rather common Some of them are disfiguring while others are dangerous The sequelæ are commonly spoken of as chronic radiodermatitis

TELANGIECTASIA

Telangiectasia (dilated cutaneous vessels) is more common after second- and third-degree reactions than after those of the first degree. But it should be particularly and forcibly emphasized that a very pronounced telangiectasia may follow a mild erythema provoked by either x-rays or radium. The dilated capillaries are seen as red

FIG. 74.—Xeroderma pigmentosum showing telangiectasia, pigmentation, keratoses and epitheliomata. Note the similarity to the so-called x-ray skin.

puncta and delicate to coarse, straight to serpentine, more or less parallel vessels which produce a brilliant red network, which at a distance, may appear as a diffused erythema. The color disappears under diascopic pressure. At times the telangiectasia, at a distance presents a macular or mottled appearance. On close inspection the macules are seen to be composed of a delicate capillary plexus.

Years ago it was common to see a very large area of telangiectasia, the entire abdomen for instance, with widespread atrophy and a central indolent ulcer or cicatrix, with multiple keratoses scattered over

the affected area. In these instances the telangiectasia seemed to radiate peripherally from the center and produced a most striking picture. Telangiectasia following second- and third-degree reactions is usually of the radiating type

FIG 75 —Telangiectasia, atrophy, pigmentation, keratoses and at the lower part a beginning epithelioma—all subsequent to severe radiodermatitis

Telangiectasia may develop within a few weeks or a few months subsequent to the advent of the reaction, but as a rule it makes its appearance in about a year. If telangiectasia has not occurred in eighteen months it usually does not appear, although cases of telangiectasia occurring several and even many years subsequent to irradiation have been recorded There is a controversy as to whether or not telangiectasia can develop in the absence of an antecedent erythema. Hazen believes that telangiectasia may occur in the absence of a previous reaction We have never seen a case of telangiectasia in which we were absolutely certain that there was no antecedent reaction Such reactions are frequently masked by inflammation due to other causes, or they may be erroneously considered the result of topical remedies and other causes Telangiectasia, in the course of time, may disappear spontaneously. Usually it is permanent. As a

rule telangiectasia reaches maximum development in a year or two, but occasionally new vessels continue to appear over a period of years

ATROPHY

Cutaneous atrophy is an exceedingly frequent sequel It practically always follows second- and third-degree reactions and may occur as a result of even mild reactions of the first degree The atrophy may be of several different clinical types After mild and moderately severe reactions the irradiated area may have a slightly lower level than that of the normal skin The most common manifestation of atrophy is wrinkling *This may be so slight as to be imperceptible except when* involving the face, particularly near the mouth, and even here it may

Fig 76 —Atrophy and wrinkling of skin of face two years after roentgen therapy

be noticed only when the muscles are used in such acts as smiling, *laughing weeping mastication etc If of a more marked degree the* wrinkling may be noticeable even when the part is in repose The extreme grade of this type of atrophy is seen in the skin of the extensor surfaces of the articulations where it may constitute an anetodermia After severe reactions the skin may be thin shiny dry scaly semi-translucent and wrinkled—resembling parchment In such instances it eczematizes and fissures readily and may reveal a lessened resistance to various kinds of traumatism Still another type of atrophy is the hidebound skin where the skin is attached to dense underlying tissues This type somewhat resembles scleroderma and is common after third-degree reactions It may also occur after repeated first-degree reactions

Like telangiectasia, atrophy can develop in a few weeks but it is most likely to appear in about a year. If it has not developed in a year or eighteen months it is not likely to appear. Unfortunately the defect is permanent. Atrophy may result without an antecedent visible reaction, the result of long-continued treatment with small doses

FIG. 77.—Depigmentation, pigmentation, atrophy and keratoses following dermatitis caused by heavily screened radium. Also permanent alopecia above the ear

PIGMENTATION.

Tanning or pigmentation is common after reactions of all degrees. As a rule it will disappear in a few weeks but it may persist for several months and even for a year or two. After very severe reactions the pigmentation may be permanent. After severe reactions there may be depigmentation instead of hyperpigmentation. This is seen most often in very dark skins.

Lentigo and diffuse pigmentation may occur to a troublesome degree in certain individuals, particularly brunettes, as a result of a few mild exposures—a dose well within that required to produce a reaction. In such instances, if the treatment is discontinued, the freckles and diffuse tanning will disappear usually in a few weeks, but they may last for months.

HAIR FOLLICLES.

When hairy parts are irradiated with sufficient intensity to effect a first-degree reaction, defluvium will occur anywhere in from one to four weeks.

Usually the hair begins to fall out about the third week and ceases to fall by the end of the fourth week Complete and permanent alopecia, with the exception of a few scattered coarse hairs and more or less fine lanugo hair, follows reactions of the second- and third-degree and well marked reactions of the first degree A fairly complete defluvium will practically always follow even a mild and transient erythema The hair will usually regrow after a mild reaction but it may not do so The follicles have been known to regenerate even after a well marked erythema that endured for two weeks It is well to bear in mind however that follicular regeneration is never certain after even a very

FIG 78 —Permanent alopecia caused by x rays

mild reaction It is possible, by the repeated application of suberythema or smaller doses to effect permanent alopecia without the advent of erythema If regeneration occurs the hair will begin to grow again in from one to six months, depending upon the dose administered If alopecia is present at the end of six months it will be permanent The mature type of hair depilates more readily than does lanugo or downy hair

SWEAT GLANDS

The coil glands may regenerate completely after a first-degree reaction but there is likely to be a noticeable diminution in the secretory function A second-degree reaction will substantially reduce the

activity of the glands and they are totally destroyed by third-degree reactions. The sudoriferous function may be lessened and even permanently arrested by repeated exposures without an accompanying reaction.

SEBACEOUS GLANDS.

A single first-degree reaction may permanently impair the function of the sebaceous glands although this is not the rule Repeated erythematous reactions or a single reaction of the second degree will reduce sebaceous activity as evidenced by a dry skin. Third-degree reactions completely destroy the sebaceous glands. As with the hair follicles and coil glands, the sebaceous glands can be reduced or even destroyed by repeated mild irradiation without a visible reaction.

MUCOUS MEMBRANES.

While we have no experimental data with which to prove the assertion, it is our impression that the orificial mucous membranes are more sensitive to *x*-rays and radium than is the skin. It has been claimed that the vaginal mucosa is more resistant to irradiation than the skin and that this resistance is caused by the acidity of the vaginal secretion. We cannot confirm these observations.

Radiodermatitis of the mucous membranes does not differ from that of the skin except for slight differences in the clinical picture. The erythema may be overlooked so that the reaction is apparently inaugurated with edema and erosion

NAILS.

Radiodermatitis of the distal end of a finger, if severe, may result in a defluvium of the nail As a rule the nail will regrow Much more common phenomena are transverse or longitudinal ridging, slow growth and brittleness of the nail following severe reactions, repeated mild reactions, or long-continued treatment without reaction.

KERATOSES. LATE ULCERATION. CANCER.

Keratoses are prone to develop eventually in so-called *x*-ray skin. They are fairly common after third-degree reactions, infrequent subsequent to reactions of the second degree unless the reaction was severe, and rarely occur as a result of a single first-degree reaction They may occur after repeated erythematous reactions and after frequent irradiation over a number of years without reaction The lesions usually occur on skin that is atrophic and perhaps telangiectatic

Keratoses are of several clinical varieties The usual type is a slight elevation consisting of a thickened but firmly adherent horny layer. The lesions range in size from a pinhead, a lentil, a split pea to a dime Another type consists of a perceptible thickening of the entire epidermis in addition to the adherent scale—acanthotic keratosis Still another

form is where, in addition to hyperplasia of the rete under the keratosis, there is associated edema and vesicle formation The vesicles are never well-developed they occur under the thickened horny layer which becomes elevated, pressure will cause a drop of serum to exude The condition is caused by a peculiar degeneration of the rete—dyskeratosis and a degeneration of the upper part of the derma X-ray keratoses, or x-ray warts as they are often designated, may be exceedingly tender

FIG 79 —Late ulcers developing in roentgen skin of the thigh

The warty excrescences may develop a few months after the healing of a severe reaction but, as a rule, it is several years before they make their appearance These keratoses are not epitheliomata, but inasmuch as many of them eventually develop into cancer they must be regarded as potentially dangerous

Ulcers may develop months, usually years, after the healing of a severe reaction or in skin that has been subjected to repeated mild reactions Schmidt has noted ulcers occurring in from three months to a year subsequent to filtered treatments, without antecedent reaction Many such ulcers are caused by traumatism acting on devitalized tissue Such ulcers may heal spontaneously or they may persist, prove recalcitrant to treatment and eventuate in cancer

There is likely to be a somewhat constant exfoliation after the healing of severe reactions The scales usually cease to form in a few months but may continue for a year or two

Cancer usually of the squamous cell variety, develops secondary to keratoses or to spontaneous ulceration Epithelioma has been known to occur within a year after the healing of a third-degree reaction but,

as a rule, this unfortunate development does not take place for several or many years.

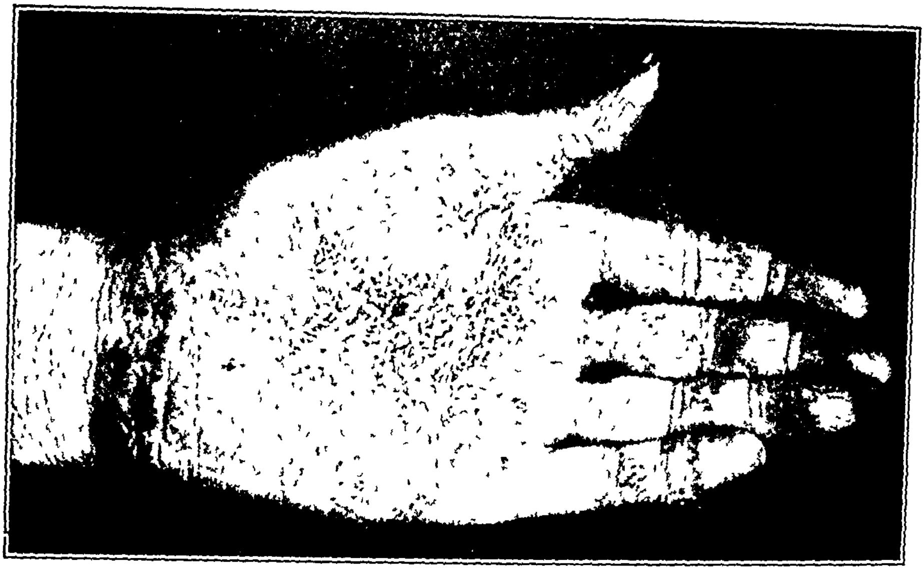


FIG. 80.—Atrophy, excessive dryness, pigmentation, telangiectasia and keratoses several years after a severe radiodermatitis

Malignant neoplasms resulting from treatment with x-rays or radium are usually of the squamous-cell (prickle-cell) variety. Baso-squamous-cell neoplasms and, occasionally, pure basal-cell tumors

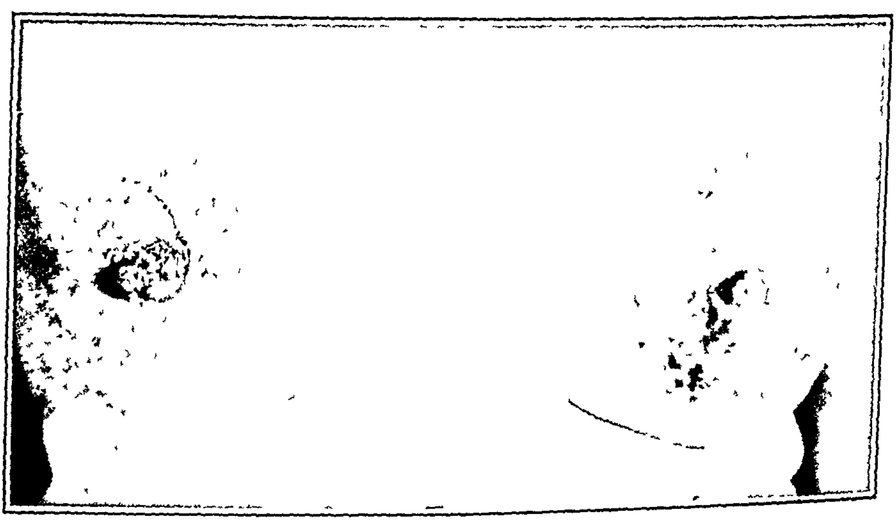


FIG. 81.—Chronic radiodermatitis of breasts Area of right nipple is ulcerating Microscopic examination revealed squamous-cell epithelioma

develop in chronic radiodermatitis. Some pathologists believe that these basal-cell lesions are not caused by the radiodermatitis, and that they would have occurred without the irradiation injury, or that

there is an erroneous histologic diagnosis. We have encountered a number of lesions that were diagnosed basal-cell growths by several histopathologists, and anaplastic highly malignant tumors by other pathologists. There have been a number of reports of spindle-cell sarcomas as a result of excessive irradiation. Most pathologists doubt that x-rays ever cause sarcoma. It is possible that these reported sarcomas are examples of so called spindle cell epitheliomas.

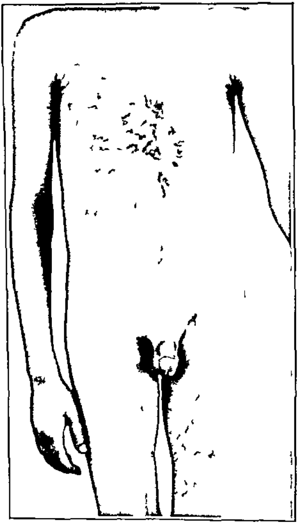


FIG 82 —Widespread chronic radiodermatitis showing atrophy, depigmentation, late ulceration and beginning squamous-cell epithelioma

CHRONIC RADIODERMATITIS

This term by some clinicians, signifies an indolent ulcer resulting from an acute third-degree reaction. Others employ it to indicate the so called x-ray skin, a skin that shows one or all of the sequelae already enumerated and which may be the result of a previous acute reaction,

or which may develop insidiously as a result of repeated irradiation over a long period of time. It is obvious that a chronic radiodermatitis

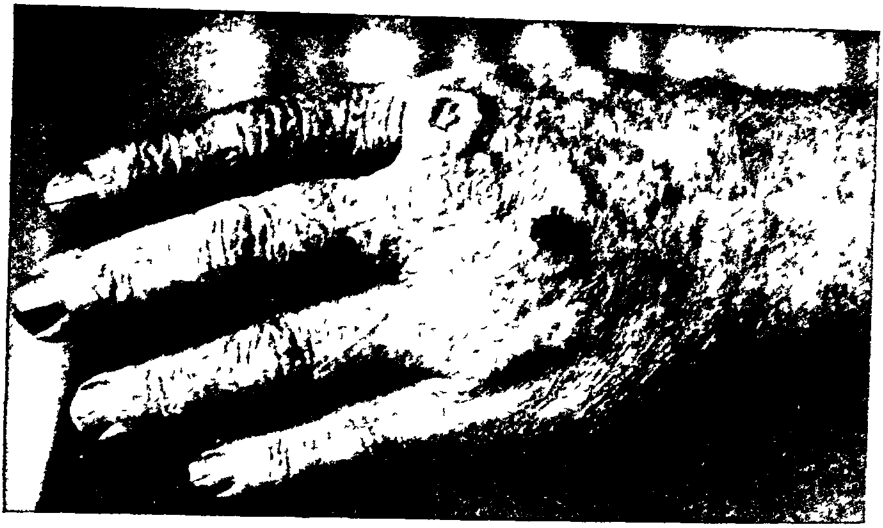


FIG. 83.—Prickle-cell epithelioma, numerous keratoses, atrophy, pigmentation and telangiectasia. This photograph could well represent the so-called x-ray skin, sailors' skin, senile skin or xeroderma pigmentosum. The patient was an x-ray technician. (Eller, courtesy of Brit. Jour. Dermat. and Syphil.)

may be atrophic, hypertrophic or ulcerative. X-ray skin bears a striking resemblance to xeroderma pigmentosum and sailors' or farmers' skin, in which there is an idiosyncrasy to sunlight or certain wave

FIG. 84.—Chronic radiodermatitis. Pigmentation, depigmentation, sclerosis and keratoses. Nodule near mouth is a squamous-cell epithelioma.

lengths thereof, and in which develop lentigo, cutaneous atrophy, ulcerations, keratoses and cancer.

Injuries to Deep Structures — The dermatologist is not particularly interested in x ray or radium injuries to the subcutaneous tissue and viscera, except the reproductive organs. The effect of irradiation on all the organs of the body is discussed in other chapters. For detailed discussion of injuries to such structures as a result of therapy with dosage and technic the reader is referred to books by I. I. Ellinger, F. H. Pohle, Otto Glasser, and Colwell and Russ (see Bibliography).

"HARD," "SOFT" AND FILTERED RAYS

There have been misleading statements relative to the difference in effect on normal skin of unfiltered and filtered radiation. The biologic action of radiation is due to that part of the radiation that is absorbed. Fewer short waves will be absorbed by a given thickness of tissue than long waves. But no matter how short are the radiations, some are absorbed by the skin. There is no fundamental difference in the biologic action of short and long wave length x rays. Naturally very "soft" rays will affect mostly the super-

Fig 85 —The photograph shows telangiectasia. The skin and subcutaneous tissue in this area are sclerotic (x ray scleroderma). Subsequently keratoses and ulcerations developed. Injury was caused by filtered radiation; an erythema ensued and disappeared in two or three weeks.

ficial tissue while very "hard" rays scatter the effect more equally throughout a greater depth. Therefore a radiodermatitis produced by "soft" radiation will be more superficial in character than will that produced by "hard" radiation. This question was touched upon in previous chapters and it will be discussed again in subsequent chapters. Let it suffice to state here that a first-, second- and third-degree radiodermatitis can be produced by x-rays and radium rays of any wave length. As will be shown in the succeeding paragraphs the type of

cutaneous reaction depends more upon the intensity-time factor than upon voltage or dosage. This question was discussed also in previous chapters

FIG 86 —Atrophy, telangiectasia and permanent depigmentation subsequent to first-degree reaction (erythema) evoked by filtered x-rays

RADIO-EPIDERMITIS AND RADIO-EPITHELITIS.

Fractionated irradiation with high voltage (180 kv. and up), heavy filtered (2 mm. lead) x-rays at long skin-target distance (75 cm.) based originally on the work of Kingery, Pfahler and Regaud, popularized by Coutard and employed by most roentgenologists for the treatment of deep-seated malignant diseases, produce a cutaneous reaction that differs from that caused by a single large dose It is not only a question of filtration, high voltage and distance, but of the time-intensity factor which is of the utmost importance With daily doses of about 200 r and a total dose, in about twenty days, of from 2000 to 5000 r, a cutaneous reaction results that is either epidermitis or epithelitis.

Radio-epithelitis consists of almost complete destruction of the epidermis including the basal-cell layer. Maximum evolution occurs on about the thirteenth day and healing is usually complete by the twenty-sixth day

In the cases of radio-epidermitis only the upper layers of the epidermis are destroyed and exposed The reaction reaches its peak

about the twenty-sixth day and disappears in about fifteen days The type of reaction depends upon both the dose and the time factor

The subjective symptoms consist of a severe burning sensation and sensitiveness Objectively, there is a dark red, intense erythema edema perhaps exudation, and usually desquamation There is usually, or often, alopecia, which may be permanent

It has been thought that such reactions do not lead to sequelæ because the true skin was not injured beyond complete repair But permanent alopecia indicates injury to the derma We have seen 'x-ray skin years after fractionated irradiation, and in the chapter on the pathology of radiodermatitis by Montgomery injury to the deep cutaneous vessels and other structures is demonstrated

GRENZ-RAY REACTIONS

The grenz rays (borderline rays) are x-rays of very long wave length (2 A average) The reactions caused by waves of this length differ somewhat from those effected by x-rays of ordinary wave length The majority of the wave lengths in the heterogeneous bundle of grenz rays are absorbed by the epidermis and upper part of the true skin Therefore the reaction, which may be intense, is likely to be very superficial With doses customarily employed for therapeutic purposes, complete recovery appears to be the rule However, some of the wave lengths are capable of penetrating to a considerable depth so that with very heavy dosage permanent injury may result Cases of telangiectasia and atrophy have been reported and have been seen by us

After an erythema dose the reaction usually develops in a few hours It lasts for one or several weeks and may be accompanied by edema, vesiculation and erosion depending upon the size of the dose The reaction is usually followed by pigmentation that may last for many months Unless the dose has been very heavy (many times the erythema dose) the hair does not fall out

RADIUM DERMATITIS

This subject can be opened with the statement that there is no essential difference between reactions caused by x-rays and those effected by radium The gamma rays and the more penetrating of the beta rays will effect the same type of reaction the same symptom-complex the same complications and the same sequelæ as will the x rays Unfiltered radium causes an exceedingly superficial reaction which may be limited largely to the epidermis Such reactions may appear very severe but they heal promptly without scarring and often without sequelæ Obviously if nothing but the epidermis is injured or if the cutis is not injured beyond complete repair, healing will be rapid and sequelæ will not develop But if the injury involves the true skin to a degree that nature can repair with difficulty or only

incompletely, the result will be slow healing and sequelæ. Keratoses, telangiectasia, atrophy, chronic ulcers and cancer subsequent to radium dermatitis, are common.

Heavily filtered *x*-rays and especially the gamma rays of very short wave length provoke a reaction that may be fairly uniformly distributed through the tissue to a considerable depth, involving not only the subcutaneous fat but thick layers of underlying muscle. The pain from these reactions is most intense and because of the absence of superficial ulceration one is apt not to recognize the seriousness of the situation for several months. We know of deaths that have resulted from reactions of this type (from heavily filtered radium) in which there was no early ulceration. In one instance the reaction extended through the entire abdominal wall. The skin was livid red, the abdomen was as hard as rock, and the pain was intolerable. At the end of several months the tissues broke down, resulting in deep ulceration. The patient died of exhaustion. In another instance the patient died before the tissue ulcerated. Postmortem examination showed sclerotic and necrosed tissue extending to the deepest parts of the abdominal wall.

In the past, when using gamma rays, it was the custom to use lead as the filter and to place the lead-covered applicator in direct contact with the skin. A long exposure with such an applicator gave rise to severe, but superficial ulcerations—reactions that healed spontaneously in a few weeks. These reactions were supposed to be due to the gamma rays and they seemed to support the contention of many physicians who persistently insisted that *x*-ray reactions and radium reactions had little in common. We know that such reactions are due to the very "soft" radiations from lead and that they can be prevented by placing suitable absorbing material (glass, aluminum, rubber, leather, paper, chamois) between the lead and the skin.

ULTRAVIOLET RAYS AS A PROPHYLACTIC AGAINST RADIODERMATITIS.

Becker in 1915 claimed to be able to increase tolerance to *x*-rays by tanning the skin with ultraviolet radiation. In 1922 Sampson made the same claim. Sampson's article evoked considerable interest and argument at the time and he received some support. Most operators of experience disagreed with his findings. It was contrary to our experience. In 1925 MacKee and Andrews reported the result of experimental work on this question. Their conclusions were that ultraviolet irradiation does not increase tolerance for *x*-rays and radium; that, in fact, it may decrease tolerance. Since then nothing has been heard of this subject.

TREATMENT OF RADIODERMATITIS.

First Degree.—There is no known way of preventing the onset of a reaction after an erythema dose has been administered. Various

prophylactic measures have been suggested for use during the latent period These consist of soothing agents, dilute solutions of acids, alkaline solutions etc, but they are of no value It is important to avoid stimulating or irritating applications previous to, during and subsequent to irradiation For the erythema the following ointment and solution will suffice

℞—Zinci stearatis		ʒj
Adipis lanæ		℥ss
Petrolati albi	q s ad	℥j
Misce		
Sig —Apply to affected parts at bedtime		

℞—Zinci oxidi, Magnesii carbonatis	āā	℥j
Calaminæ præparata		ʒss
Aquæ hamamelidis		℥j
Liquoris calcis	q s ad	℥iv
Misce		
Sig —Shake well and sop on affected parts several times daily		

If itching is present 1 or 2 grains of menthol or 3 to 5 grains of phenol may be incorporated in the ointment To the solution may be added from 1 to 10 grains of menthol and from 15 to 30 drops of carbolic acid

During the acute stage soap and water should be avoided cleansing being accomplished with one of the following mixtures

℞—Phenolis liquefacti		gtt xv
Olei olivæ		℥iij
Petrolati liquidi	q s ad	℥vj
Misce		

℞—Magma magnesiæ		℥iv
Petrolati liquidi		℥ij
Sodii boratis		ʒj
Aqua rosæ	q s ad	℥viij
Misce		

If the reaction is severe with considerable burning a wet dressing is likely to prove soothing For this purpose one may employ aluminum acetate a 25 to 50 per cent solution of the watery extract of witch-hazel milk of magnesia diluted or in full strength lead and opium wash (filtered) olive oil, or carron oil

Second Degree —Here we are dealing with a broken epidermis and more or less exudation If there is active exudation ointments should be avoided because they obstruct drainage The serum lifts the ointment preventing the ingredients from contact with the affected surface flows from under the ointment comes in contact with the surrounding normal skin and may give rise to eczema

If the exudate is not heavy it is permissible to employ a paste as the large starch content will permit absorption and evaporation

℞—Zinci oxidi, Amyli	āā	ʒij
Petrolati albi	q s ad	℥j
Misce		

The paste is to be applied at night and removed in the morning with the albolene and olive oil cleansing solution. The calamine lotion may be employed during the day If there is considerable discharge it is advantageous to employ one of the enumerated wet dressings day and night during the stage of active exudation In severe reactions the patient is likely to complain bitterly of burning pain and almost every application will become uncomfortable if it is not so when first applied. In such instances it becomes necessary to change from one solution to another until something will be found that can be tolerated White of egg, the moss preparations and various other emollients may prove useful in individual instances Acids and alkaline preparations do not seem to possess special value Starch poultices are useful at times but, as a rule, wet dressings are preferred by the patient An emulsion consisting of 1 ounce of magnesium carbonate to 7 ounces of carron oil is a good application for these reactions

In the nonexudative stage, a cream may be more cooling than an unguent Unguentum aquæ rosæ (U S P) may be employed for the purpose, or one of the following creams in which may be incorporated such chemicals as zinc oxide, zinc stearate, calamine, etc , according to indications From $\frac{1}{2}$ to 2 grains of menthol may be added for the cooling effect

	Per cent
℞—Olei theobromatis	18
Ceræ albæ	10
Adipis lanæ	6
Olei amygdalæ expressi	50
Aquæ	16
℞—Adipis anserini	65
Olei theobromatis	12
Adipis lanæ	15
Aquæ	8
℞—Olei olivæ	65
Olei theobromatis	5
Adipis lanæ	5
Ceræ albæ	5
Aquæ	20

The various almond and quince-seed emulsions, and witch-hazel creams, alone or combined with other chemicals, can be used to advantage at times

If none of the suggestions already given affords relief from the pain, from 5 to 10 per cent of benzocaine may be added to the ointment, paste, solution or emulsion This drug at times seems to act exceedingly well Beta-eucaine-lactate, in the same proportion, or butysin picrate, will afford relief in some instances Occasionally 1 or 2 grains of menthol, phenol, eucalyptus or camphor, when added to the prescription, seems to lessen the pain Local remedies placed on a thick crust will be of little benefit If not adherent, it is preferable to remove the crust if there is much pain If not, and there is no exudation, it is better to leave the crust alone Not infrequently a patient becomes

sensitized to drugs such as benzocaine and butyn picrate If so, a troublesome complication arises in the form of dermatitis venenata Very weak ichthyol applications may prove beneficial at times Ichthyol in the strength of from 1 to 3 per cent may be added to the ointments pastes and creams or the following lotion may be tried

℞—Ichthyol
Oleatum zinci āā ℥ss
Magnesii carbonatis ʒij
Liquoris calcis q s ad ℥viij
Misce

Third Degree —The most difficult problem in the treatment of reactions of the third degree is to obtain relief from the severe pain Patients will welcome any new local application only to throw it aside in an hour or two One remedy after another will be tried until the resources of the pharmacopœia and of the physician are exhausted Fortunately by that time the pain will begin to lessen and the remedy that is being used at the time, or the physician who prescribes it will receive the credit Psychologic influence can be used to advantage, tact, patience and constant encouragement are essential In addition to the remedies already enumerated an icebag placed on a wet dressing may effect temporary relief During the stage of gangrene or sloughing local remedies are of little use The injection of local anesthetics in and around the affected area seems to afford very little comfort and is not a good practice The weight of bed clothes thick pads and bandages are not well borne and should be avoided

It is almost always necessary to resort to the internal administration of sedatives for the first few weeks or months Bromides and the coal-tar preparations are practically useless except in mild cases Codeine and morphine will give relief but they must be used very cautiously and intelligently in order to avoid the acquisition of a drug habit *Aspirin is sometimes useful*

After separation of the slough the pain can usually be controlled by local applications Slight stimulation is now indicated For this purpose the ichthyol lotion or a zinc ointment or paste containing from 1 to 3 per cent of ichthyol may be employed Care must be taken not to injure or overstimulate the delicate granulations If exuberant they may be destroyed with the curette and a 10 per cent solution of silver nitrate It is permissible to stimulate sluggish granulation tissue by applications of silver nitrate, beginning with a 1 per cent solution

Indolent ulcers can often be made to granulate and heal by exposure to the sun or to artificially produced ultraviolet radiation The exposures at first should be very mild but later the strength should be sufficient to effect a mild erythema of the adjacent normal skin Two treatments a week will suffice Scarlet R medicinal ointment, 0 5 to 5 per cent, and other dyes such as gentian violet may be of benefit in some instances

Excellent results have been obtained with the jelly obtained from the leaf of a plant called aloe vera. The plant grows in Florida. The leaf is green in color and long and wide, somewhat like a sword. The shell of the leaf is thick and tough, but when fresh can be cut easily with a knife. On one side of the leaf the shell is flat; on the other side it is convex. There is a thick layer of jelly-like substance between the shells. The leaf should be kept in a cool, moist environment. It is customary to cut a piece of the leaf to the size and shape of the lesion. The convex shell layer is removed. The jelly is placed in contact with

Fig. 87

Fig. 88

Fig. 87.—Chronic radiodermatitis before operation. (Courtesy of Dr. John Staige Davis, Am. Jour. Roentgenol., 29, 43, 1933.)

Fig. 88.—Same as Fig. 87 after a plastic operation performed by Dr. John Staige Davis.

the floor of the ulcer and held in position with a bandage. Dressings are changed once or twice daily. The treatment is inefficacious for roentgen or radium sequelæ—atrophy, telangiectasia, sclerosis and keratosis. It appears to be most effective in the case of indolent roentgen and radium ulcers.

To obtain satisfactory results it seems necessary to use the fresh leaf. Preparations on the market which contain the aloe vera jelly have been thus far unsatisfactory. It is thought that the good results are due to vitamin D. For this reason a number of dermatologists

FIG. 89.—Indolent roentgen ulcer. (Courtesy of Dr. John Staige Davis. Am. Jour. Roentgenol. 29: 43, 1933.)

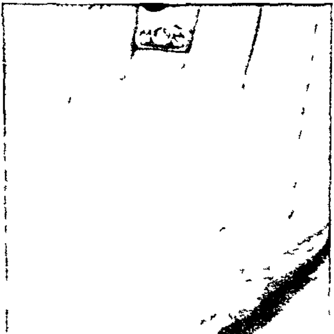


FIG. 90.—Same as Fig. 89 after a plastic operation performed by Dr. John Staige Davis.

are now experimenting with ointments containing cod-liver oil and other vitamin D preparations but the method has not yet been evaluated. An ointment containing penicillin is thought to be efficacious by some dermatologists. We are not convinced that an ointment containing radon is efficacious for the treatment of radiodermatitis In fact, we are of the opinion that further radiations can only aggravate tissue that has been damaged with x-rays or radium

Everything considered, especially in persons who have a long expectancy of life, the best treatment for a third-degree radiodermatitis, if not too extensive and unsuitably located, is surgical excision If the entire affected area is removed the pain ceases at once and healing is rapid. If the excision is wide and sufficiently deep, grafts and flaps

Fig 91

Fig 92

Fig 91 —*X*-ray ulcer of long standing (Courtesy of Dr John Staige Davis, Am Jour Roentgenol, 29, 43, 1933)

Fig 92 —Same as Fig 91 after a plastic operation performed by Dr John Staige Davis

take well. This saves months of agony, additional months of inconvenience and, most important of all, it precludes the subsequent development of sequelæ This is an important point because if an ulcer heals spontaneously or as a result of topical applications, the resultant scar will be always a menace because of the possibility of the ultimate development of cancer During the acute stages it is difficult for the surgeon to ascertain the extent, especially the depth, of the injury so that surgical intervention may be a complicated matter Furthermore, surgeons do not like to operate in such cases because the reparative powers of the tissues are so poor. In some instances ablation can be accomplished In others, some form of plastic surgery is indicated. In still others it is better to avoid surgical interference at

Fig 93 —Chronic radiodermatitis of anal region before surgical treatment (Courtesy of Dr John Staige Davis Am Jour Roentgenol 29 43 1933)

Fig 94 —Same as Fig 93 after a plastic operation performed by Dr John Staige Davis

Fig. 95 —Chronic radiodermatitis requiring amputation of a finger

Fig. 96

Fig. 97

Fig. 96 —Chronic radiodermatitis before plastic surgery

Fig. 97 —Same as Fig. 96 after plastic surgery performed by the late Dr C A Porter

least until the extent and degree of injury together with the ability to repair, has been determined Very successful work of this kind has been done by Porter McArthur, Davis Sheehan McPhee, Gillies and McIndoe Shore, Blair, Brown and Hamm Webster Figi New and Dix Pack, Martin Aufricht Adair Martin and many others In fact most plastic surgeons and cancer specialists are kept busy repairing *x*-ray and radium injuries We advise surgery, whenever possible, in cases of third-degree reactions indolent ulcers and areas of *x*-ray skin

FIG 98 FIG 99

FIG 98 —Chronic radiodermatitis before surgical intervention

FIG 99 —Same as Fig 98 after excision of most of affected area by the late Dr George D Stewart

FIG 100 FIG 101 FIG 102

FIG 100 —Chronic radiodermatitis before plastic operation (Courtesy of Drs Blair Brown and Hamm)

FIG 101 —Same as Fig 100 after transference of graft

FIG 102 —Same as Figs 100 and 101 showing end result of plastic operation (Courtesy of Dr V P Blair Dr J B Brown and Dr W G Hamm Radiology 19 337 1932)

Treatment of Sequelæ —*Pigmentation* —The disappearance of freckles and diffuse pigmentation may be hastened at times by a liquid or emulsion containing 2 grains of corrosive mercuric chloride to the ounce

℞—Hydrargyri chloridi corrosivi		gr vj
Glycerini		℥j
Tincturæ benzoini		℥ss
Emulsionis amygdalæ	q s ad	℥iij
Misce		

The emulsion may be applied to the affected parts two or three times daily At times an ointment or cream is more efficacious It may be applied at bedtime.

℞—Bismuthi suboxidum, } Hydrargyri ammoniati }	āā	ʒj
Olei lavandulæ		♏x
Adipis lanæ		℥ss
Petrolati albi	q s ad	℥j
Misce		

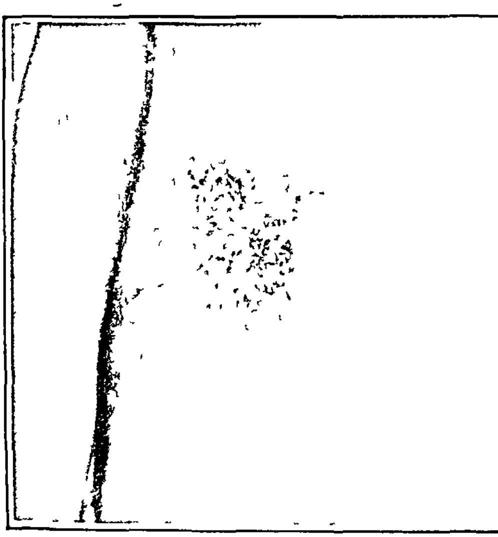


Fig 103

Fig 104

Fig 103 —Chronic radiodermatitis before plastic operation (Courtesy of Drs Blair, Brown and Hamm)

Fig 104 —Same as Fig 103 after plastic operation (Courtesy of Dr V P Blair, Dr J B Brown and Dr W G Hamm, Radiology, **19**, 337, 1932)

Fig 105 —Radiodermatitis showing widespread telangiectasia, excessive dryness and numerous keratoses There was an area of ulceration at the wrist It was excised and skin-grafted (Private patient of Dr Fred Wise, operation performed by Dr C A Porter)

FIG. 106.—*A* and *B*. Chronic radiodermatitis subsequent to X-ray treatment of hypertrichosis sixteen years previously. *C*, A lateral thoracic pedicle flap now encircles the neck, being attached at either end. *D*, Final result of repair. (Courtesy of Figi, New and Dix: Surg., Gynec. and Obst., 77: 284, 1943.)

pressed firmly against the skin for purposes of dehematization, and an exposure of five seconds given. If the skin is not unduly sensitive the exposures are increased gradually to one and then to three minutes. Exposures of five and even ten minutes have been given but three minutes is the usual amount. This produces a bullous reaction that heals in from one to two weeks. Treatments are given at intervals of from two to four weeks. Normal skin around small areas can be protected by employing a quartz front-piece of suitable size or by using a piece of black cloth containing a hole of the right size. It is a good plan to begin with small doses (just enough to cause erythema) and increase cautiously. The results are not always satisfactory. After the telangiectasia has disappeared there may be considerable atrophy and depigmentation, which was present before the ultraviolet treatment but which was hidden by the telangiectasia. Grenz rays have been used for the purpose but we believe that they are contraindicated. Thorium X, and radon, in water and in oil or grease, and radium pads have been used for telangiectasia, especially in Germany Excellent results have been claimed. These methods have not been fully evaluated.

At the best, telangiectasia is a very difficult condition to master and it is only by perseverance and the careful employment of the enumerated methods of treatment that even partial success can be attained. It can be camouflaged by various preparations for this purpose that are now on the market.

Atrophy.—There is little if anything that can be done for this sequela. Rarely there is spontaneous improvement. Persistent massage may accomplish some good.

Dry Skin.—Dry skin is due in part at least to lessened activity of the coil glands and sebaceous glands. Unless these appendages have been totally destroyed there is likely to be some regeneration. The treatment for such skin is protection from the cold and the free application of oily emulsions, creams and ointments

Alopecia—There is no successful treatment for *x*-ray alopecia Wigs, of course, can be used.

Keratoses.—The treatment of *x*-ray keratoses and *x*-ray cancer will be found in the chapters dealing with these conditions. Small superficial keratoses can be destroyed with electrodesiccation under local procaine anesthesia.

Summation and General Advice.—Chronic radiodermatitis (*x*-ray skin; radium skin) because of the sequelæ enumerated above is disfiguring, especially on the exposed parts, and, of more importance, it is dangerous Cancer incidence in such skin is high. The percentage incidence is about 25 or 30. While chronic radiodermatitis of severe type is more prone to eventuate in cancer than is that of mild degree, yet many severe cases never become malignant, while some mild cases do develop malignancy. Specific treatment for the various defects or sequelæ is given in this and other chapters. Excellent judgment is neces-

sary for the management of x ray skin Some patients are philosophic, even indifferent, others are badly frightened Each case must be judged by itself Surgery is indicated when there is the slightest suspicion of beginning malignancy, or when there is recurrent ulceration, or many keratoses but surgery is not necessary for every case If the skin is behaving reasonably well and the patient does not desire surgery for esthetic reasons, or when extensive areas are involved, or the location is unfavorable for surgery, all that is necessary is for the physician to inspect the skin at regular intervals—at least once yearly This periodic inspection is important and should be continued throughout the life of the patient If, at any time, a suspicious area should develop, the particular area should be adequately treated by modern conventional established methods

We have been watching a large number of such patients for many years Many of them are able to camouflage the disfigurement satisfactorily with well known preparations for this purpose that are on the market

BIBLIOGRAPHY

AXMANN H Beseitigung der durch Radiumstrahlen bewirkten Gefa serweiterungen München med Wchn chr 54 1877 1907 The Removal of the Dilated Vessels Caused by Radium Treatment Arch Roentg Ray 12 329 1908

———— The Removal of the Dilated Vessels Caused by Radium Treatment Arch Roentgen Ray 12 329 1908

BECKER P F Beitrag zum Kapitel der Rontgenschadigungen und deren Behandlung mit Quartzlampe und gedampften Hochfrequenz tiomen Strahlentherapie 6 405 1915 Zur kosmetischen Verbesserung der Rontgenstrahlennarben mittels Fibrolysininjektion und Quartzlampenbestrahlung Fortschr a d Geb d Rontgenstrahlen 14 175 1909

BÉCLÈRE H Les rayons de Rontgen dans le traitement des tumeurs hypophysaires du gigantisme et de l acromégalie Arch d élect méd 23 325 1915

BLAIR V P BROWN J B and HAMM W G The Surgical Treatment of Post Radiation Keratosis Radiology 19 337 1932

COLWELL H A and RUSS S X Ray and Radium Injuries Prevention and Treatment London Oxford University Press Humphrey Milford 1934

COUTARD H Principles of X Ray Treatment of Malignant Disease Lancet 2 1 1934

DAVIS JOHN STAIGE Treatment of Deep Roentgen Ray Burns by Excision and Tissue Shifting Jour Am Med Assn 86 1432 1926

———— Clinical Illustrations of Deep Roentgen Ray and Radium Burns Am Jour Roentgenol and Rad Ther 29 43 1933

DODD W J Treatment of Acute Roentgen Ray Dermatitis Am Jour Roentgenol (n s) 1 430 1913-1914

ELLINGER F The Biologic Fundamentals of Radiation Therapy English translation by Reuben Gross New York Interscience Publishers Inc 1941

ENGMAN Quoted by Schamberg J F Remarks Upon the Microbacillus of Seborrhea (Sabouraud)—Preliminary Report Upon an Examination of the Sebaceous Glands of the Nose Jour Cutan and Genito-Urin Dis 20 99 1902

FIGI F A NEW G B and DIX C R Radiodermatitis of the Head and Neck with a Discussion of Its Surgical Treatment Surg Gynec and Obst 77 284 1943

FORDYCE J A Infectious Eczematoid Dermatitis Possible Influence of Anaphylaxis in Skin Reactions Jour Cutan Dis 29 129 1911

HAZEN H H Ultraviolet Ray in the Treatment of Roentgen Ray Telangiectasis Am Jour Roentgenol 9 101 1922

HULL A J The Treatment of Burns by Paraffin Brit Med Jour 1 37 1917

MCARTHUR L L Surgery of X Ray Lesions Am Jour Roentgenol 4 521 1917

MACKEE G M and ANDREWS G C Coolidge Tube Quantitative Variations Am Jour Roentgenol 11 525 1924

MacKee, G M, and Andrews, G C.: Inverse Square of Distance Law for Filtered Roentgen Radiation, Am Jour. Roentgenol, 12, 58, 1924
———— The Ultraviolet Ray as a Prophylactic Against Radiodermatitis, Jour Am. Med Assn, 85, 1715, 1925.
Morton, J. J A Rapid Method for the Diagnosis of Renal Tuberculosis by the Use of the *X*-Rayed Guinea Pig, Jour. Exper. Med, 24, 419, 1916
Murphy, J B Heteroplastic Tissue Grafting Effected Through Roentgen-Ray Lymphoid Destruction, Jour Am Med Assn, 62, 1459, 1914
Pfahler, G. E: Sudden Swelling of the Parotid Gland Following Shortly after *X*-Ray Treatment Its Probable Cause and Means of Prevention, Jour. Cutan Dis, 31, 396, 1913
Pohle, E A Theoretical Principles of Roentgen Therapy, Philadelphia, Lea & Febiger, 1938
Porter, C A Surgical Treatment of Roentgen-Ray Lesions, Am Jour. Roentgenol, 13, 31, 1925
———— The Surgical Treatment of *X*-Ray Carcinoma and Other Severe *X*-Ray Lesions, Based upon an Analysis of Forty-Seven Cases, Jour Med Res., 21, 357, 1909
Sampson, C M Ultraviolet and *X*-Ray as Physiologic Complements in Therapeusis, Am Jour. Roentgenol, 9, 570, 1922
Schmidt, H E: Spätschädigungen der Haut und innerer Organe nach therapeutischer Röntgenbestrahlung, Deutsch med Wchnschr., 39, 1553, 1913
Schultz, F.: *X*-Ray Treatment of Skin Diseases, Translated by James Burnet, New York, Rebman Company, 1912, p 23.
Simpson, F E.: *Radium in the Treatment of Cancer and Various Other Diseases of* the Skin, Jour Am Med Assn, 67, 1508, 1916

CHAPTER XXIII

PATHOLOGIC HISTOLOGY OF RADIODERMATITIS

By

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Many histopathologic studies have been made of acute and chronic roentgen dermatitis and radium dermatitis,[8,15,31,33,38,54,55,57] and also of the effects of grenz rays and thorium X. Correlation of pathologic, histochemical, chemical, and physical studies have been carried out in many instances both on man and experimental animals.[13,1-5,3-4,56,57] There still remain a few facts that are disputed and findings that contradict one another.[15,33] Space does not permit detailed discussion of these controversial views; they are reviewed in articles in Jadassohn's Handbuch[18,27,3,49] and also in text books on histopathology of the skin.[16,24,30] Many of the older articles in the literature are difficult to evaluate in terms of modern dosage in roentgens. Also in many of those articles distinction was not made among the types of radiation employed, whether soft, hard, or mixed, nor were the effects of secondary radiation from screening, and so forth, evaluated. In reports of observations based on irradiation of animals, often there is failure to recognize that histopathologic changes, especially in the epidermis, may not concur with those of human skin. Thus, Ellinger emphasized that the skin of rabbits has two and a half times the tolerance to x rays that is possessed by human skin. The so-called erythema dose, as employed by dermatologists in this country, represents much less in roentgens than the old erythema dose used in Europe.[14] The accurate analysis of an erythema dose by spectrophotometric studies[19] as contrasted with visual estimation of erythema is too complex for practical use. It is obvious that histopathologic changes seen following an erythema dose as compared with the ulceration which may follow greater doses, will vary considerably, no matter what type of radiation is employed. This applies chiefly to the acute effects of irradiation. The following observations are given on the basis of the review of the literature together with my own observations, including an unpublished study of the histopathologic changes in 2 cases of acute and in 63 cases of chronic radium dermatitis and roentgen ray dermatitis made by me.

At the risk of repetition certain other fundamental facts must be kept in mind. With infrared rays, sunlight and even with ultraviolet rays, the primary effects on the skin are those of heat, as emphasized by Miescher,[36,37] although any or all of these methods of irradia-

tion was seen after treatment with 9 kilovolts than with 13 kilovolts, which is to be explained by the fact that in the former more of the rays affect the epidermis. Erythema resulting from grenz rays appears within one or two days after relatively small dosage but epilation and destruction of hair follicles result only from many times the erythema dose The erythema from grenz rays occurs in cycles similar to those described by Miescher[33] in relation to ordinary roentgen rays Milbradt expressed the belief that the histopathologic changes following treatment with therapeutic doses of grenz rays more closely simulate those caused by ultraviolet rays than those caused by *x*-rays of usual wave length, in that the epidermis is chiefly affected, even though there is no tendency towards formation of vesicles such as is seen in dermatitis from irradiation with ultraviolet radiation Rottmann found sweat glands affected in grenz-ray dermatitis only after intensive treatment The deeper bloodvessels in the cutis, however, are often affected and changes in the cutis and pigmentation in the epidermis may be seen only three months after all treatment has been stopped Rottmann, Herxheimer and Uhlmann, Pohle and Bunting,[45,46] the latter on the basis also of studies of capillaries, all regard the histopathologic changes following grenz irradiation to be similar to those of dermatitis caused by *x*-rays of usual wave length Bucky acknowledged that histopathologic changes in the bloodvessels in the cutis may occur after grenz-ray therapy and may be demonstrated years later

It is apparent, then, that the histopathologic changes following mild irradiation with 9 kilovolts are confined chiefly to the epidermis and simulate those induced by ultraviolet radiation, whereas dermatitis following treatment with 13 kilovolts or following more intensive dosage with 9 kilovolts, results in permanent changes in the structure of the cutis, including thickening of the cutis and obliterative changes in the vessels which may be indistinguishable from those seen in radiodermatitis caused by shorter wave lengths Histopathologic studies of grenz-ray dermatitis simply confirm, therefore, the recent clinical observations that grenz rays in moderate doses are relatively harmless but that excessive doses may result in telangiectasia[1] and ulceration entirely similar in their pathologic aspects to those seen in ordinary chronic radiodermatitis, one may even anticipate, in the future, reports of malignant changes

Histopathologic changes following thorium X dermatitis were thoroughly studied by Lomholt, who found edematous changes in the epidermis, areas of cellular necrosis and increase in connective tissue and in fibroblasts The inflammatory reaction about the bloodvessels was similar to that seen in roentgen dermatitis, but the changes in the cutis were less marked Kuznitzky and Jacoby[23] expressed the belief that the changes in the vessels are secondary to toxic substances rather than to direct action of the rays The effects of thorium X on the skin are probably comparable to those caused by grenz rays.

ACUTE RADIODERMATITIS

Many of the older systematic histologic studies in regard to radiodermatitis were made on small animals. Colwell and Russ[9] reviewed the work thoroughly up to 1924. Recent studies of acute radium dermatitis apparently have been confined to observations on animals but the effects reported so closely parallel those of acute roentgen dermatitis affecting human beings and animals that it is scarcely necessary to consider radium dermatitis separately. The only exception is radium dermatitis following unfiltered application of radium to the skin. The alpha and soft beta rays, acting primarily on the epidermis may result in superficial ulcerations which heal promptly. Rost[4–49] emphasized that there is no essential difference between the histopathologic picture resulting from application of hard and filtered roentgen rays and soft and unfiltered roentgen rays and that the skin does not have an increased tolerance to filtered rays. It is important to bear in mind the varying sensitivity of different structures in the skin. Thus, Borak found the lethal dose for the sebaceous glands to be 1200 r for the hair follicle 1600 r, for the epidermis, 2000 r, and for the sweat glands, 2500 r. he found that severe damage to sweat glands and to bloodvessels parallel one another and that little permanent damage results to either with milder irradiation. It is well known that the basal layer of the epidermis and of the hair papillæ is sensitive to irradiation. Irradiation, however affects all the cells in the skin in varying degrees the effect of the rays apparently is on the nuclei and results in changes in the viability of the cells and in their powers of reproduction.[3,4,15,4,47,48]

Miescher[33] has made an exhaustive study on man of the effects of roentgen rays using an erythema dose of varying intensity with mild filtration.

The following were the factors. Coolidge tube 25 cm point gap, 2 milliamperes 1 mm aluminum filter 24 cm skin distance, skin of ankles upper arm, back, or breast were used exposures of twenty thirty and thirty five minutes were given. Miescher described three cycles of erythema with a wave occurring between the first and fourth days a second between the eighth and twenty second days, a third between the thirty fourth and fifty first days with a great variation in different individuals between the slightest visible erythema and development of ulceration. His findings have been confirmed in studies of capillaries made by Pohle[43,44] and most recently by Harris, Leddy and Sheard[19] using spectrophoto-analysis of the color of the skin following irradiation by roentgen rays. The later observers failed to find it as intensive a reaction with the third wave as in the first two waves also they determined that the pigmentation of the skin follows a course independent of the course of the erythema. Zurhelle[56,7] found in studies of animals similar cycles of radium erythema with histopathologic changes paralleling those described by Miescher in studies of human beings.

In the first cycle Miescher found only slight changes in the epidermis including occasional mitosis in contrast to definite infiltration of the cutis which appeared twenty four hours after irradiation. There was a perivascular infiltration of round cells dilatation of the superficial vessels and interstitial

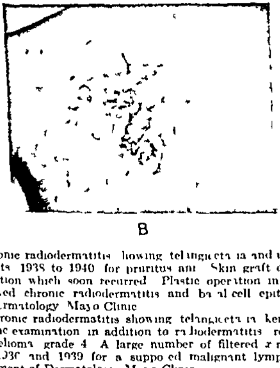
infiltration of the hair follicles with polymorphonuclear leukocytes. The sweat glands particularly were surrounded by more or less rich infiltration of polymorphonuclear leukocytes and lymphocytes. In the following days the inflammation disappeared, with the erythema and the morphologic appearance approaching normal. Occasionally there was a little evidence of pigmentary activity in the basal-cell layer. Miescher found that with the appearance of the second cycle, between the tenth and twentieth days, characteristic changes occur in the epidermis, these consist especially of the formation of multinucleated cells There may be shedding of the stratum corneum, occasionally areas of parakeratosis are seen. Inflammation of the cutis is mild In the third cycle the intercellular spaces of the epidermis become widened, the cells swollen, there is marked colliquative (liquefaction) necrosis of the basal-cell layer, with more intensive irradiation, in the epidermal cells there are marked pyknosis and amitotic cell division, together with degeneration in the form of hydropic swelling, to the point of their becoming unrecognizable Thinning of the epidermis and flattening of the rete ridges are frequently seen There is slight to marked edema of the fibroblasts and endothelial cells, together with amitotic cell division, the latter resulting in multinucleated fibroblasts, endothelial cells, muscle cells and even fat cells Occasionally the second and third cycles merge together, in which case the second cycle assumes the characteristics of the third cycle There may be a definite increase in fibrous tissue but no appreciable changes are to be seen in the elastic tissue

Miescher emphasized that the ability of the epithelial cells to become multinucleated is of pathologic significance, that the multinucleation resembles that seen in precancerous and carcinomatous processes, so that the histopathologic changes in the epidermis in the third cycle of roentgen dermatitis may be indistinguishable from the picture of Bowen's disease or of senile keratosis. Multinucleated cells in the cutis are of less significance, as they may be encountered in any granulation tissue The epidermis, after the end of the acute reaction, remains atrophic, or it may be thickened or hyperkeratotic, for a shorter or longer time and the same is true in regard to increase in pigmentation. Some months, or perhaps a year or more after irradiation, evidence of cellular damage is found in the cutis, with thickening of the bloodvessels, obliteration of their lumens and degenerative changes in connective tissue and muscles Miescher disagreed with Gassmann, who found primary hyperplasia of the endothelial cells, Miescher found that this occurred only in the end stage of the third cycle

The typical histopathologic picture of acute radiodermatitis of the chest of ten days' duration, corresponding to Miescher's second cycle, or wave, is shown in Fig 109 There is definite edema in the upper cutis, with resultant flattening of the epidermis, loss of the rete ridges and separation of the elastic tissue from the epidermis Corresponding to the observations of others, but in contrast to Miescher's findings, there is definite homogenization of the connective tissue and early edema of the endothelial cells of the smaller vessels In some of the vessels of the deeper cutis and of the subcutaneous tissues there were proliferation and fibrotic changes of the intima The edema of the upper cutis probably is to be explained on the basis of disturbance of water balance In one area, about a sweat duct, there was rather marked infiltration, composed chiefly of lymphocytes and polymorphonuclear leukocytes and

PLATE I

A



B

A.—J. L. Chronic radiodermatitis showing telangiectasia and ulceration. Total of 1 x-ray treatments 1938 to 1940 for pruritus ani. Skin graft over coccyx in 1941 because of ulceration which soon recurred. Plastic operation in 1944. Microscopic examination showed chronic radiodermatitis and basal cell epithelioma. Courtesy Department of Dermatology, Mayo Clinic.

B.—G. T. Chronic radiodermatitis showing telangiectasia, keratoses and multiple ulcers. Microscopic examination in addition to radiodermatitis revealed multicentric prickle cell epithelioma, grade 4. A large number of filtered x-ray treatments were given between 1936 and 1939 for a supposed malignant lymphoma of the lung. Courtesy Department of Dermatology, Mayo Clinic.

A

B

C

A — L H Chronic radiodermatitis the result of removal of foreign bodies with aid of *x* rays in 1943 Ulcer is covered with a yellow adherent slough General pathologist reported inflammation Dr Hamilton Montgomery made the correct histologic diagnosis of chronic radiodermatitis Courtesy Department of Dermatology Mayo Clinic

B — H V O Radio-epidermitis on twenty first day of fractionated *x* ray treatment consisting of 75 r twice daily filtered radiation with 200 kilovolt — total 3 200 r in air Clinically there is dull red erythema edema and desquamation The histopathology of this case is given in the chapter on pathologic histology of radiodermatitis by Dr Hamilton Montgomery Courtesy Department of Dermatology Mayo Clinic

C — J P W Radio-epidermitis showing erosion surrounded by some telangiectasia and atrophy Between June 12 and July 8 1940 patient received 19 fractionated filtered *x* ray treatment Photograph was taken 3 months later (October 10 1940) Diagnosis confirmed by histologic examination Courtesy Department of Dermatology Mayo Clinic

eosinophil The sebaceous glands in this one case apparently remained unaffected In Fig 110 (specimen by courtesy of Dr Fred Weidman) is shown the effect of two weeks after filtered irradiation of a nevus In this

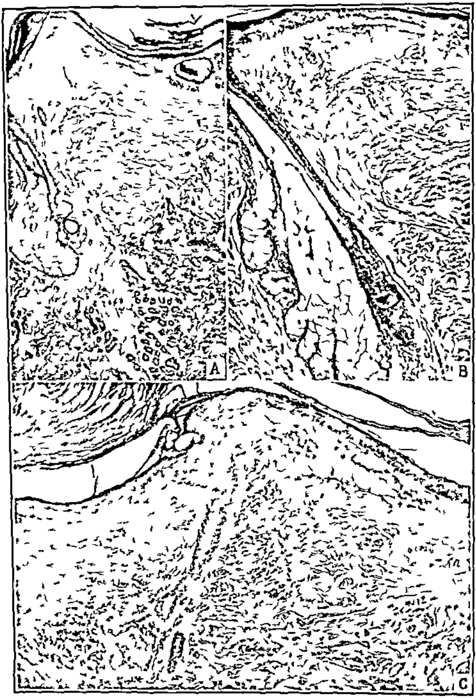


FIG 109 —*A* Acute radiodermatitis of chest of ten days duration Edema and rarefaction of connective tissue beneath epidermis telangiectasia homogenization of connective tissue about hair follicle perivascular infiltrate about sweat glands lack of destruction of sebaceous gland (× 35) *B* Flattening of epidermis through edema and separation of elastic tissue which is still preserved (× 70) *C* Same changes also perivascular leukocytic infiltrate and increase of endothelial cells (× 125)

result of edema. In the cutis the capillaries were swollen and so were the fixed connective tissue cells. Wood illustrated edematous changes in the larger vessels in the cutis three days after three erythema doses of roentgen rays had been given.

To these descriptions may be added the not infrequent occurrence of infiltrate about the cutaneous nerves; the early disintegration of the lipoid cells in the sebaceous glands was emphasized by Halberstaedter. Edematous to atrophic changes in the hair follicles and sweat glands are seen after intensive irradiation.

When intensive dosage results in acute ulceration there is a region of necrosis containing serum, disintegrated collagen and elastic fibers, an infiltrate composed chiefly of polymorphonuclear leukocytes, and a varying degree of destruction of the epidermal appendages. The depth of the necrosis, in turn, is dependent on the intensity of the irradiation. Miescher has shown that when epithelium regenerates over an area where ulceration has resulted from acute radiodermatitis, the epidermis usually is thickened and hyperkeratotic and no longer contains multinucleated cells.

Epithelitis and Epidermitis.—These terms with or without the prefix "radio" have been applied to cutaneous and deeper reactions associated with protracted fractional irradiation of either cutaneous or internal malignant lesions according to the principles outlined by Coutard. The clinical aspects of epithelitis and epidermitis are considered in Chapter XXII. In my experience and also that of other physicians in the Clinic and elsewhere with whom I have talked, epithelitis and epidermitis frequently result in telangiectasia, atrophy, and, at times, ulceration of the skin, and are not necessarily transitory, benign reactions as many writers would maintain. Friedman and Rosh[35] described a rhythm of irradiation effects somewhat similar to cycles of erythema observed by Miescher in cases in which acute radiodermatitis followed single erythema doses of roentgen rays of varying intensity. Thus, with the type of filtered irradiation usually employed, epithelitis developed about the tenth day and epidermitis began on the sixteenth day and reached a second-degree intensity around the thirty-second day. The time factor for these reactions, however, varied with the type and intensity of irradiation employed.

According to Borak[36] if single daily doses are limited to 100, 200 or 300 r, no telangiectasia developed even after a total dose of 4800 r. This is contrary to our experience at the Clinic as we have seen telangiectasia and atrophy develop, for example, even after a total dose of only 3040 r of filtered irradiation with 200 kilovolts divided into twenty daily treatments of 152 r each and applied to each side of the neck for carcinoma of the larynx. In this case, a specimen of the skin of the neck taken one and a half years after roentgen therapy revealed a typical histologic picture of chronic radiodermatitis with atrophy of the epidermis and dermal appendages, fibrosis, and obliterative changes in the vessels. There had been no recurrence of the carcinoma.

I recently saw another patient, who, a year previously, had been treated elsewhere for carcinoma of the urinary bladder. He received daily doses of 200 kilovolts of filtered irradiation for one month, or a total dose of 3000 r to each of two fields directed to the anterior wall of the bladder. On the subsequent seventeen days a total of 2940 r was applied through two posterior fields. When the patient was

FIG 111 —Epidermitis of skin of neck on twenty first day of fractional 76 r twice daily filtered roentgen ray irradiation with 200 kilovolts (total 3 200 r in air to each side of neck) given for carcinoma of the larynx. *A* Relative hyperkeratosis atrophy of epidermis and hair follicle liquefaction degeneration of basal cell layer absence of sebaceous glands and dilatation of capillaries (as in Fig 110 *A*) also thickened thrombosed vessel at X (× 60). *B* Same lesion deep in cutis. Small blood vessel at X with edema of its walls and proliferation of endothelium and large vessel just beneath with similar but extensive degenerative changes (× 170)

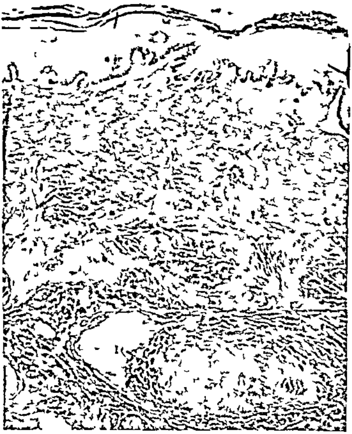
examined in the Clinic there was no evidence of tumor of the bladder on cystoscopic examination. The patient had a Grade 1 radiodermatitis of the lower part of the abdomen and a deep Grade 3 ulceration in the sacral region over the coccyx between the gluteal folds. A specimen of the ulcer revealed a severe chronic radiodermatitis with marked acanthosis but no definite malignant change. In the latter case however the severity of the dermatitis suggested that

there may have been a fault in some arrangement of the fields, for example, overlapping.

It is unfortunate that relatively few histopathologic studies have been made of the cutaneous reactions resulting from daily irradiation à la Coutard. Borak stated that atrophy of the epidermis with loss of papillary bodies is a sequel to epidermitis but that the deeper vessels are not involved as in other methods of treatment. It is difficult, however, to explain radiodermatitis accompanied by ulceration without accepting that the deeper vessels in the cutis are injured by this type of irradiation (see Fig. 111).

Summary.—The histopathologic changes in acute radiodermatitis may be summarized as follows: Within forty-eight hours, in the epidermis, are definite changes which become more marked in the second and third cycles of erythema and vary greatly according to the degree of reaction. There are increase in shedding of the stratum corneum; occasionally parakeratosis and also increase in the stratum granulosum; edema and vacuolization of the prickle cells; a varying degree of amitotic cell division; liquefaction necrosis of the basal-cell layer; spotted, increased pigmentary activity of the basal cells and also deposit of melanin in the chromatophores in the cutis at the periphery of the process. The epidermis is frequently atrophic and flattened by edema and rarefaction of the connective tissue in the upper parts of the cutis. The papillary bodies and rete ridges thus may be obliterated. Telangiectasia is a common, almost a constant, finding. A varying degree of infiltrate is seen throughout the cutis and especially about the hair follicles and sweat glands The degree of infiltrate varies in relation to the cycles of erythema. Early degenerative changes are seen in the sebaceous glands, less frequently of the hair follicles and sweat glands By the time of the third cycle, or wave, definite proliferative changes can be seen, especially of the intima of the smaller bloodvessels. Edematous and proliferative changes in the walls of the vessels in the cutis are sometimes encountered, even as early as the third to the fifth day after irradiation. The elastic tissue may be frayed and splintered but as a rule it remains unaltered in amount or arrangement. It is not clear whether changes in the collagen fibers precede changes in the epidermis. Apparently alterations in the connective tissue may not appear until months after the irradiation has been given. When ulceration occurs there is necrosis of all parts of the affected skin. Pigmentation results in varying degree but usually is more marked at the periphery of the region of radiodermatitis. Healing may take place so that, three years after first-degree radiodermatitis, histologic examination may be entirely negative or there may be histologic and clinical evidence of telangiectasia or of atrophy, or both, associated with atrophic to hyperkeratotic changes in the epidermis. Conversely, permanent changes in the cutis, including telangiectasia and thickening and obliterative changes in the deeper vessels, may first become manifest,

PLATE III



Chronic Radiodermatitis (Same as Fig 114)

Young connective tissue staining yellow contrasted with older red staining homogenized fibrous strands. Extensive fibrous replacement of intima, media and adventitia of large thickened vessel. Van Gieson stain (× 25)

either clinically or pathologically, several years after irradiation. These changes may progress and result in chronic ulceration and may eventuate many years later in keratosis or malignant change.

Epithelitis and epidermitis which occur after protracted fractional irradiation as employed in the treatment of neoplasms are not always benign reactions but may result in varying degrees of acute and chronic radiodermatitis.

CHRONIC RADIODERMATITIS

The histopathologic picture of chronic radiodermatitis is fundamentally the same, whether it is the result of single or of multiple doses of filtered or of unfiltered roentgen rays or radium rays or whether it is the result of diagnostic procedures, including roentgenoscopy. The histologic picture varies with the severity of the reaction and the duration of the process, it also depends on whether keratosis or malignant change has developed in the region of the radiodermatitis. These degrees of change from mild, residual atrophy, telangiectasia and pigmentation to keratosis and severe third degree ulceration, with or without malignant changes, are best illustrated in Figs 112 to 122 and Plates III and IV. The fundamental pathologic change in chronic radiodermatitis is that of fibrotic thickening of the walls of the vessels in the deeper portions of the cutis, with varying degrees of occlusive changes in the lumens of these vessels. As a rule, the size of the region of ulceration, when ulceration is present will be dependent on the extent and depth of involvement of the underlying bloodvessels. We shall describe the various changes in the epidermis and cutis, leaving until later discussion of malignant changes. In many of the 63 cases of chronic radiodermatitis recently studied, stains for lipoids mucin and hemosiderin gave essentially negative results. Acknowledgment must be made especially of Wolbach's[54 55] detailed observations regarding changes in the connective tissue. Histopathologic studies apparently have not been made in regard to changes in the nails.

In chronic radiodermatitis there is usually hyperkeratosis and increase in the stratum granulosum together with thickening of the prickle cell layer, usually without changes in the normal appearance or arrangement of the cells (Figs 112 to 114 and Plate III). Relatively little edema is to be seen. At the edge of an area of ulceration there may be increased thickening of the epidermis (Fig 112 *A*) or marked thinning. Pseudo-epitheliomatous hyperplasia of the epidermis which frequently is seen at the edge of many types of ulcers, is rarely encountered in chronic radiodermatitis. Increase in melanin pigmentation in the basal and dendritic cells of the epidermis occasionally may be seen in spotted areas presumably representing areas unaffected by the irradiation, but frequently this pigmentation is absent. In the end stages of reactions which clinically are of the first degree, the epidermis is flattened and atrophied, with loss of the rete ridges. There

is pyknosis of some of the basal cells, many of which contain varying amounts of melanin pigment. (Figs. 116 and 117, *B*)

Just beneath the epidermis, where atrophy has not occurred, papillary bodies may be almost completely filled by large, dilated lymphatic structures with capillary vessels. (Figs 114 and 117, *A*.) Wolbach emphasized that regeneration of the epidermis may extend beneath thrombosed telangiectatic capillaries or beneath small areas of necrotic corium, so that the telangiectatic tissue may become completely separated from the skin by the layer of regenerative epidermis and may persist for a time as a dry, dark-colored spot, a "coal spot," until it is cast off. We observed this phenomenon in only two of our series of cases (Fig 120), although in many of the cases there was a varying degree of dilatation of the superficial bloodvessels and lymphatics in the papillary bodies of the upper cutis. As the result of a varying degree of lymphedema just beneath the epidermis, Lücken, or spaces, are also found. (Figs 117, *A*, to 121 and Plate IV.) The edema results in rarefaction of the collagen fibers and at times in flattening of the

FIG 112 —*A*, Chronic radiodermatitis, treatment for eighteen months for lupus erythematosus, ulceration three months later. Benign thickening of epidermis at margin of ulceration. Increase in elastic tissue in some areas, decrease in others, marked occlusive changes in blood-vessels. Cutaneous nerve at "x". Acid orcein stain (× 31). *B*, Chronic radiodermatitis. Occlusive changes in vessels, atrophy of sweat glands and homogenization of connective tissue and nerve at "x". Elastin H stain (× 60).

Roentgen keratosis of hand at left side early squamous cell epithelioma Grade 1 ı ııı showing individual cell keratinization homogenization of connective tissue basophilic staining of elastic and collagen tissue fibers with hematoxylin eosin stain obliteratation of superficial vessels Lucken and dilatation of vessels fibrotic occluded vessels at x (X 60)

epidermis from edema similar to that seen in acute radiodermatitis (Fig 116) In one area of roentgen dermatitis of twenty five years duration there were large superficial vessels lying just beneath the epidermis, the walls of which appeared to be made up of hyalinized fibrous tissue, lacking in nuclei or other signs of viability and beneath the hyalinized fibrous tissue there was first a loose areolar connective tissue and then a dense area of homogenized collagen fibers with no evidence of cellular activity (Fig 117 A) Wolbach expressed the

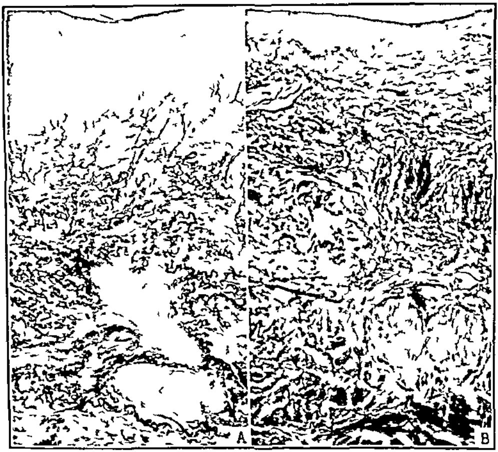


FIG 113 — *A* Chronic radiodermatitis of breast ten months duration Atrophy of dermal appendages homogenized arrectores pilorum muscles surrounded by swollen and clumped fragmented elastic fibers Normal elastic tissue strands in upper cutis (× 100) *B* Similar case Atrophy of epidermis vacuolization of muscle bundles spotted increase in elastic tissue (× 85)

belief that the epidermis tends to migrate down into areas of edematous and rarefied collagen fibers

If the vascular changes are followed further the dilated telangiectatic vessels usually can be seen to arise from existing capillaries and from vessels deeper in the cutis which latter may or may not give evidence of obliterative changes in their lumens Dependent on the severity of the process more superficial and deeper vessels respectively are affected in varying degrees and number The various changes in the vessels

FIG 114 —Chronic radiodermatitis, single roentgen treatment fifteen months before for psoriasis of hand, followed in ten days by exfoliation and ulceration Increase in Gitterfasern in pars papillaris and between younger lighter staining connective tissue fibers, also in nerve bundle at "x", remnants of sweat glands, large fibrosed vessel containing many fine Gitterfasern resembling elastic fibers Maersch-Bielschowsky stain (× 45)

are illustrated in Figs 112 to 122 and Plates III and IV It is scarcely accurate to speak of "obliterative endarteritis" or "endophlebitis" because all the layers of the walls of the vessels are involved essentially in a process of replacement by fibrous tissue with resultant marked thickening of the media and adventitia, as well as of the intima The endothelium often is composed of swollen and vacuolated cells which frequently form tufts of cells projecting into the lumen (Fig 115) The replacement of musculature of the coats of the vessels by collagen fibrous tissue and by Gitterfasern, which latter according to recent investigators are probably varieties of young connective tissue fibers, although resembling elastic fibers in many respects are best shown in Figs 114, 115, *B*, and Plate III, all representing the same case and in Fig 122, *C* The elastic tissue in the walls of the vessels may be destroyed especially that in the adventitia and media but it usually is preserved and almost always there is a permanent ring of normal to swollen and curled elastic tissue fibers remaining in the intima making it easy to recognize the altered bloodvessels with the aid of various elastic tissue stains The extensive fibrous replacement of the intima media and adventitia helps to distinguish the vascular changes in chronic radiodermatitis from those seen in occlusive vascular diseases, especially of the extremities Furthermore, there is usually marked or even complete, absence of inflammatory reaction about the vessels, the exception being vessels occurring in a zone of ulceration and necrosis and adjacent to a region of malignant change True thrombosis and recanalization of vessels is an infrequent finding, the occlusion usually results gradually through fibrous replacement of the intima and through proliferation of endothelial cells

Changes in connective tissue predominate and justly have been emphasized by Wolbach In chronic radiodermatitis in contrast to acute radiodermatitis, there is less new formation of fibrous tissue with increase in fibroblasts and nuclei The collagen, except just beneath the epidermis, presents a homogenized and hyalin-like appearance, as a rule the cells do not have many nuclei and inflammatory infiltrate is lacking (Fig 117 and Plate III) The normal arrangement of the collagen bundles may be broken up and they may appear fragmented and irregularly arranged (Fig 115, *A*) There is very definite increase in thickness of the entire cutis Occasionally connective tissue cells with very large or multiple nuclei are encountered (Fig 117 *B*), others, of which the nuclei are small, may be difficult to distinguish from endothelial cells without special staining In third degree radiodermatitis atrophy of the fat cells and subcutaneous tissues is seen associated with increase in interceptal bundles of fibrous tissue (Fig 118 *C*) With Maersch Bielschowsky stain Gitterfasern frequently are seen to be increased throughout the cutis and subcutaneous tissue, especially adjacent to bloodvessels and where there is evidence of formation of young connective tissue (Figs 114 and 122 *C*)

Cutaneous nerves vary greatly in size, depending on the site from

which the specimen for biopsy is taken. Occasionally there is an infiltrate of lymphocytes about them; more frequently there are increases in connective tissue and Gitterfasern in the nerve bundles

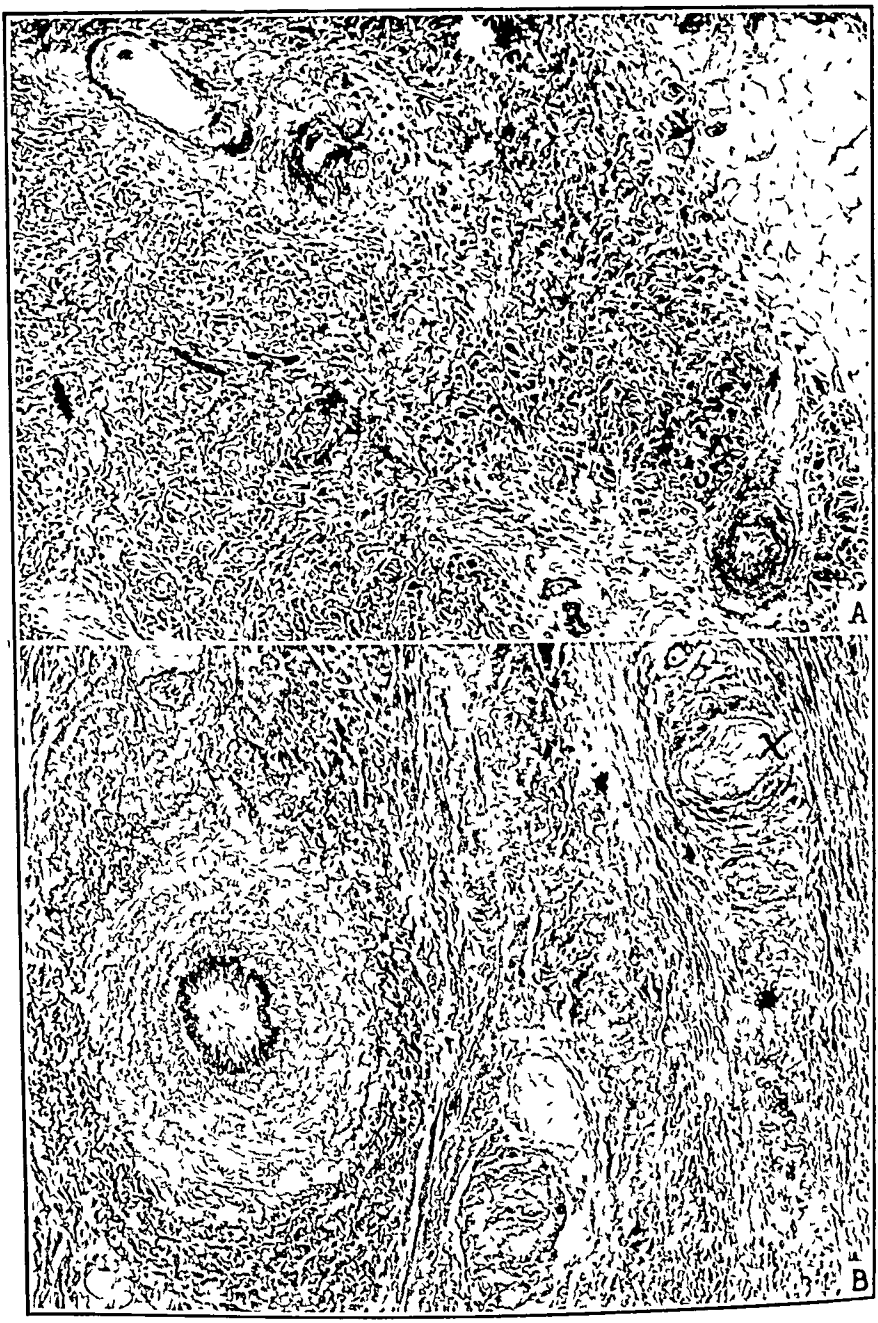


FIG 115 —*A*, Chronic radium dermatitis near groin Fragmentation and homogenization of collagen and loss of elastic tissue, except about atrophied hair follicle and sweat glands and in thickened walls of blood-vessel in deep cutis (× 45) *B*, Chronic roentgen dermatitis (same case as Fig 114 and Plate III) Elastic tissue in thickened walls of occluded vessel, absent in small vessel, nerve bundle at "x" and in homogenized sclerotic tissue Elastin H stain (× 48)

(Figs 114 and 122) At times edematous and fibrotic changes are seen resulting in an apparent increase in size (Figs 112 *B*, 115, *B*, and 122 *C*) Histopathologic studies with present methods of staining do not, however, afford any explanation for the pain associated with many cases of chronic radiodermatitis In severe cases of chronic radiodermatitis there may be complete destruction and absence of many nerve bundles

The dermal appendages are affected in varying degrees, depending on the severity of the process Except in mild reactions of the first degree the sebaceous glands are completely destroyed and the same is true of the hair follicles, although rudimentary remnants may be seen surrounded by a zone composed of fibrous tissue and at times of Gitterfasern and elastic fibers (Fig 116 *A*) The sweat ducts, and more particularly the sweat glands, are destroyed only by severe, third degree injury, in fact their changes parallel the destructive changes seen in the deeper vessels (Fig 112, *B*) Smooth muscles have been thought to be enlarged In milder degrees of dermatitis there is hyalinization and hydropic degeneration rather than true hypertrophy (Fig 113) With reactions of more severe degree, destruction and absence of demonstrable arrectores pilorum muscles may occur

Much has been written about increase and decrease of elastic tissue fibers and about basophilic staining of elastic and collagen fibers It is my experience that the elastic tissue fibers are relatively unaltered in mild degrees of radiodermatitis, although there may be fragmentation and clumping of the fibers as the result of edema, and the swelling of the fibers gives the false appearance of a real increase (Figs 113 116 *B* 119 *B*) On the other hand in areas of recent replacement by fibrous tissue there is apparently a definite attempt at new formation of fine, elastic fibers such as also has been reported by Gans and take place in scleroderma and striæ cutis distensi (Fig 113, *B*) With more severe degrees of radiodermatitis there is a disappearance of the elastic tissue fibers in papillary bodies and throughout most of the areas of homogenized connective tissue together with a varying degree of preservation or destruction of elastic fibers in the walls of the blood vessels (Figs 112 115 119 *B*)

Basophilic staining of collagen fibers and merging of collagen and elastic tissue may result and the two types of tissue may be indistinguishable one from the other (Figs 113, *B* and 119, *B*) The staining of elastic tissue fibers with ordinary hematoxylin-eosin preparations is a phenomenon frequently encountered in association with all degrees of radiodermatitis involving the exposed surfaces (Plate IV) These changes are not characteristic of radiodermatitis but are commonly seen in so called senile skin including sailors' or farmers' skin, and in lupus erythematosus occurring on areas of the body exposed to light and the elements Neither in lupus erythematosus nor in my recent series of 63 cases of chronic radiodermatitis were basophilic

staining phenomena apparent in specimens for biopsy taken from areas protected from the sun and the other elements

Chronic ulceration from radiodermatitis results in a superficial to deep zone of necrosis, containing serum and polymorphonuclear leukocytes; in this zone also are evident destruction of various appendages

FIG 116 —*A*, Mild chronic radiodermatitis, ten years' duration *Atrophy of epidermis*, increase in melanin pigmentation in basal and dendritic cells and in chromatophores in cutis Edema and loose, areolar connective tissue in upper cutis with dilatation of superficial lymphatics and capillaries Homogenization of connective tissue in mid-cutis Absence of *inflammatory* reaction Van Gieson stain (× 195) *B*, Similar changes showing preservation of elastic tissue (× 105)

and structures in the cutis affected At the base of the zone of necrosis the bloodvessels will be found to have undergone occlusive changes Remains of elastic tissue fibers frequently are seen in the necrotic mass (Fig 118)

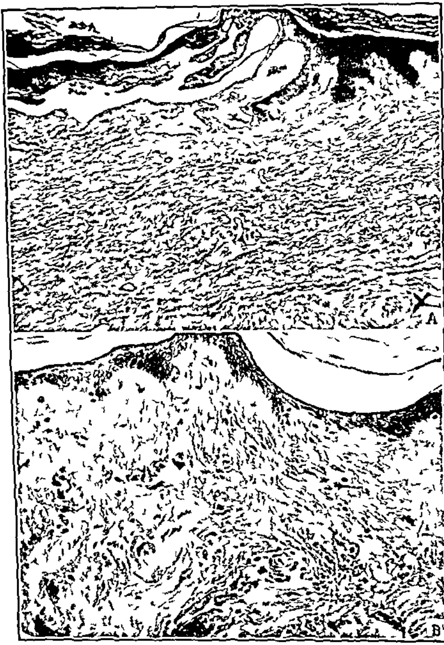


Fig 117 — A Twenty five roentgen treatments for eczema behind knee twenty five years previously Enormously dilated lymphatics and capillaries hyalinized and homogenized connective tissue in mid cutis occluded vessel at x absence of infiltrate and dermal appendages (× 30) B Roentgen and radium scar three years after irradiation for carcinoma of the breast Atrophy and vacuolization and pigmentation of cells of epidermis homogenization of cutis and multinucleated cells (× 195)

There may be secondary infection and inflammatory reaction with a varying degree of infiltrate, not only of polymorphonuclear leukocytes which occur primarily in the necrotic zone, but also of lymphocytes and plasma cells.

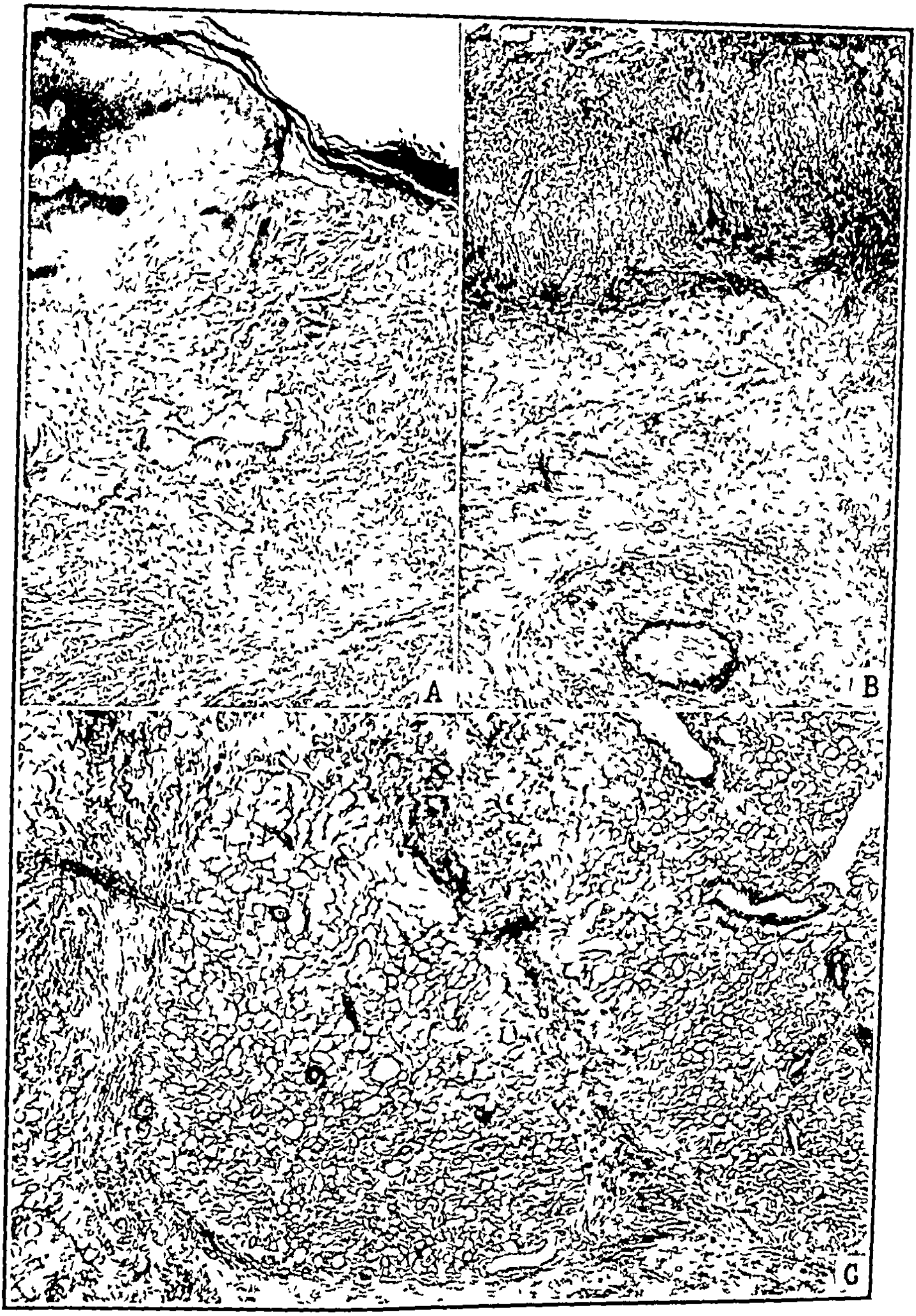


FIG 118 —*A*, Chronic radiodermatitis, filtered irradiation for uterine neoplasm, edge of chronic third-degree ulcer on thigh, showing epithelial proliferation, dilatation of vessels, fibrosis, and absence of dermal appendages (× 28) *B*, Remnants of elastic tissue fibers in necrotic ulcer, and large, occluded bloodvessel (× 50) *C*, Fat necrosis and fibrosis of subcutaneous tissue Elastin H stain (× 30)

EPITHELIOMATOUS CHANGES IN CHRONIC RADIODERMATITIS

Recently a study was made of 259 cases of chronic radiodermatitis.[51, 5] If one excludes the patients with injuries of the first degree (simply atrophy, telangiectasia and pigmentation), in 19 per cent of the cases of chronic radiodermatitis of the second and third degrees, squamous cell epithelioma developed, the malignancy of the growths varied from Grade 1 to Grade 4. This percentage of epitheliomatous change undoubtedly would have been higher if the patients had been observed for more than five years. *Epithelioma may develop as a sequel to* radiodermatitis as long as twenty years after irradiation has been given.[10, 11] Malignant change takes place most frequently in relation to roentgen or radium keratosis but also frequently it is seen originating *in ulcers*. Several older articles *in the literature cited a mortality* of 20 to 25 per cent. In 8 of 27 of my cases in which there were epitheliomatous changes squamous cell epithelioma of Grades 3 and 4 was found; this is indicative of the fact that a serious prognosis must be offered in many cases of chronic radiodermatitis. Ghormley and Fairchild[16] have reported similar findings. Leddy and Rigos[14] reported that epitheliomas occurred in 33 per cent of 115 cases of radiodermatitis in which the patients were physicians.

Mention already has been made of multinucleated epithelial cells and of individual cell keratinization resembling an epithelioma *in situ* occurring in association with acute radiodermatitis. This, however, appears to be a reversible reaction as is also the reaction in the early stages of experimentally produced roentgen keratosis and epithelioma and in tar cancer of animals.[17, 1, 53] In chronic radiodermatitis over a period of years areas of hypertrophy of the epidermis become more marked, developing clinically into keratosis, and in these areas are seen histologically, the phenomenon of individual cell keratinization, ami-*totic and mitotic cell division and dyskeratosis, in other words all the* features of an epithelioma *in situ* (Figs 119, 120 and Plate IV). There is usually a sharp line of demarcation between the basophilic-staining hyperplastic epidermis and the eosin acidophilic staining of keratotic areas of the epidermis *where malignant change is in progress*. It is my experience that the majority of epitheliomas arising from lesions of radiodermatitis start out as epitheliomas *in situ*, later penetrating and invading the cutis (Fig 121 *B*). The histopathologic changes in the epidermis duplicate those seen in cases of Bowen's disease and of senile tar and arsenical keratosis and in many cases of leukoplakia of the mucous membranes, in all of which conditions epitheliomatous change takes place in 20 per cent or more of the cases. It therefore seems illogical to treat these conditions by radiotherapy unless intensive doses are administered. Roentgen and radium keratosis differ from the other forms of keratosis just mentioned in that in roentgen and radium keratosis there is usually relatively little evidence

of inflammatory reaction in the cutis, and obliterative changes in the lumens of the larger vessels predominate

Jorstad and Lane have emphasized the fact that both tar and roentgen rays act as lipoid solvents in producing keratosis in the skin, and Guldberg emphasized the toxic effects of tar on both the corium and the epidermis It is my impression that roentgen and radium keratoses are seen as a rule in examination of those individuals who

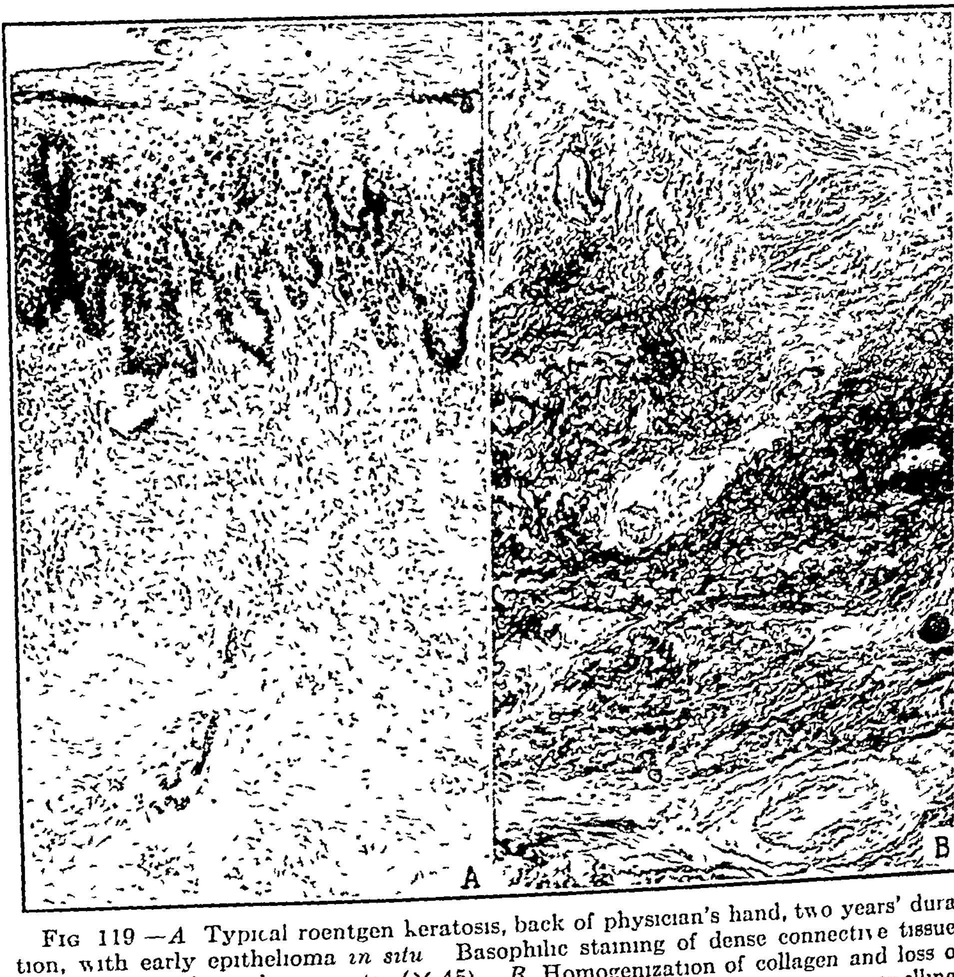


FIG 119 —*A* Typical roentgen keratosis, back of physician's hand, two years' duration, with early epithelioma *in situ* Basophilic staining of dense connective tissue, thickened vessels in deeper cutis (× 45) *B*, Homogenization of collagen and loss of elastic tissue in upper cutis, merging of connective tissue and elastic tissue, swelling, curling, and fine, newly formed elastic fibers in mid-cutis (× 65)

have been subject to repeated irradiation, with resultant chronic and irritating toxic effects on the epidermis and the cutis; the changes induced predispose certain individuals to the development of epithelioma I agree with Wolbach[55] that squamous-cell carcinoma in association with radiodermatitis may result from conditions continuously calling forth proliferative activities on the epidermis over a period of years, but I cannot concur in his conception that the epidermis is a transparent tissue and is not injured in the passage of the rays, or

that the changes in the epidermis are only secondary to lesions in its supporting tissue, the corium

Epithelioma may also arise from ulcers produced by treatment with superficial or deep roentgen rays and by radium, again these epitheliomas are squamous cell in type and are of varying degrees of malignancy. The epitheliomatous process may start as an epithelioma *in situ* with later invasion and metastasis, but more frequently ordinary types of invading squamous cell epithelioma are seen (Fig 121 *A*) I have yet to see a true sarcoma arising from chronic radiodermatitis. Whereas cases have been reported rarely in the literature,[10 5] careful analysis reveals most of the malignant growths to be highly undifferentiated squamous-cell epithelioma, Grade 4, simulating in morphologic features, a sarcoma (Fig 122) It is questionable whether basal cell epithelioma ever results from radiodermatitis, its occasional association probably is merely coincidental. It is the impression of many authors, and it is also my own impression without there being any definite data on the matter, that epithelioma rarely develops following a single massive dose of roentgen rays or radium. This concept is exemplified by the infrequent development of epithelioma following irradiation in the treatment of internal malignancy which irradiation has resulted in third-degree ulceration of the skin. This would fit in with the relatively infrequent occurrence of epitheliomas in scars and ulcers resulting from heat or from various chemical burns

DIFFERENTIAL DIAGNOSIS

The histopathologic picture of acute radiodermatitis is not always distinctive. The combination of histologic changes seen in chronic radiodermatitis are usually specific and diagnostic and have proved of contributing value in certain medicolegal cases. Thus, any radiotherapy resulting in permanent telangiectasia, or in more severe changes, will leave histologic evidence of fibrosis and thickening of the cutis, atrophy of the sebaceous glands and the hair follicles, and thickening and obliterative changes in the lumens of a varying number of blood-vessels in the cutis and deeper structures. Failure to demonstrate occlusive changes in some of the vessels practically excludes the diagnosis of chronic radiodermatitis assuming, of course, that a specimen for biopsy was taken from a representative area

There are several conditions which may simulate to a varying degree, the histopathologic changes seen in chronic radiodermatitis. Differential diagnosis of roentgen and radium keratosis from senile, arsenical, and other keratosis already has been mentioned. Clinical differentiation however is usually easily made. In lichen sclerosus et atrophicus[4 a] in kraurosis vulvae and in balanitis xerotica obliterans, there are tremendous edema and rarefaction in the upper part of the cutis, which compress the epidermis. In the last two conditions there may be some thickening of the walls of the bloodvessels. The three con

FIG 121 —*A*, Edge of roentgen ulcer of physician's hand, showing squamous-cell epithelioma Grade 2, invading cutis and occluded bloodvessel at "x" (× 42) *B*, Roentgen keratosis adjacent to area shown in Plate II Squamous-cell epithelioma, Grade 2, *in situ*, with early invasion of cutis, dyskeratosis with amitotic and mitotic cell division, dilated lymphatics and Lucken in epidermis, elastic fibers staining with hematoxylin in upper cutis (× 110).

FIG 122 —Chronic radiodermatitis of cheek following treatment in beauty parlor for hypertrichosis *A* Squamous cell epithelioma Grade 3 simulating basal cell epithelioma basophilic staining of collagen fiber absence of dermal appendages thickened bloodvessels and sclerotic enlarged nerve bundle at x (× 28) *B* Adjacent area squamous cell epithelioma Grade 4 simulating a sarcoma (× 80) *C* Increase in Gitterfasern in walls of bloodvessel and nerve bundles fibrous replacement of subcutaneous tissue Maersch Bielschowsky stain (× 54)

paralleling the effects of gamma rays and *x*-rays of ordinary wave lengths.

The histopathologic changes in radium and roentgen dermatitis are not essentially different. The summary of acute changes, concerning which there is some divergent opinion, already has been given. When irradiation has resulted in permanent damage to the cutis and to the bloodvessels contained therein, then there develops a chronic radiodermatitis, varying in nature from telangiectasia and pigmentation to second- and third-degree reactions, with keratosis and small or large ulcers. The epidermis may be thickened, atrophic, or ulcerated. Pigmentation varies in amount, but is minimal compared to that of acute radiodermatitis. Thickening of the cutis is almost always present, with fibrosis and homogenization of connective tissue fibers. Frequently rarefaction of the collagen, the result of edema, is seen in the upper cutis. A uniform fibrotic thickening of the intima, media, and adventitia of many of the larger and deeper vessels occurs and results in occlusive changes, frequently in ulceration of the epidermis. The elastic tissue is not altered in mild degrees of radiodermatitis but may be destroyed in severe degree of reaction. Sebaceous glands are early affected and later destroyed; the same usually is true also of the hair follicles. Remains of sweat glands and arrectores pilorum muscles are seen in all but the most severe reactions of the third degree. Telangiectasia of the superficial lymphatic structures and capillaries is a fairly consistent finding in chronic radiodermatitis, but in cases of long standing this process may undergo gradual involution and may disappear entirely. Cutaneous nerves may not be affected; on the other hand, they may be swollen, fibrotic or destroyed. There is usually an increase in *Gitterfäsern*, especially where new formation of connective tissue has taken place and especially in relation to the bloodvessels. Basophilic staining of the collagen and elastic fibers, and merging of the two types of fibers, usually are seen in chronic radiodermatitis involving the surfaces of the body which are exposed to light and to the other elements but these changes also are seen in other dermatoses in the same area. Roentgen and radium keratosis and ulcers result in epitheliomatous changes in about 20 per cent of the cases. The neoplasms are practically always squamous-cell epitheliomas varying in malignancy from Grade 1 to Grade 4 and metastasis and death may result. Various physical and chemical explanations for the reactions of roentgen and radium rays on the skin are discussed in other chapters in this book.

BIBLIOGRAPHY

1. Andrews, G. C.: Diseases of the Skin; a Textbook for Practitioners and Students. Philadelphia, W. B. Saunders Company, 1930, p. [illegible].
2. Bloch, Bruno: Cancers and Precancerous Affections From the Dermatological Viewpoint. Cancer Rev. 7: 65, 1932.
3. Blumenthal, Franz: Strahlenbehandlung bei Hautkrankheiten. Berlin, S. Karger, 1925, p. [illegible].

4 Blumenthal Franz Paradoxical Influence of Light Rays as a Causative and Curative Factor in Cancer of the Skin Arch Dermat and Syph 33 1042 1936

5 Bode H -G Ein weiterer Beitrag zur Histologie sensibilisierter rontgenbestrahlter Haut Strahlentherapie 40 515 1931

6 Borak J The Radiation Biology of the Cutaneous Glands Radiology 27 651 1936

6a ———— Radiation Effects on Blood Vessels I Erythema Edema II Inflammation Degeneration Suppression of Growth Capacity Retrogression Necrosis III Telangiectasis Effects on Lymph Vessels Radiology 38 481 607 718 1942

7 Bucky Gustav Grenzstrahltherapie Leipzig S Hirzel 1928 p 153

8 Cole H N Chronic Roentgen Ray Dermatoses as Seen in the Professional Man Jour Am Med Assn 84 865 1925

9 Colwell H A and Russ Sidney Radium X Rays and the Living Cell 2d ed London G Bell & Sons 1924

10 ———— X Ray and Radium Injuries Prevention and Treatment London Oxford University Press 1934 p 1

11 Darier J La radiodermite ulcéreuse et les lésions histologiques Ann de dermat et de syph 5 s 3 541 1912

12 Delafield Francis and Prudden T M A Text book of Pathology 16th ed Baltimore W Wood & Co 1936 p 1406

13 Ellinger F Untersuchungen über die Hautwirkungen von Rontgenstrahlen am Kaninchen II Mitteilung Weitere Untersuchungen uber die Wirkung mittelharter Strahlung am Kaninchenohr Strahlentherapie 47 517 1933

14 Epstein Stephan The Importance of Overlapping in Irradiation of the Scalp With Comments on the Tolerance of the Skin for Soft Rays Brit Jour Dermat and Syph 48 1 1936

15 Fahr T Die Haut unter dem Einfluss der Rontgenstrahlen Virchows Arch f path Anat 254 277 1925

15a Friedman Milton and Rosh Rieva The Rhythm of Radiation Effects Further Studies of Protracted External Irradiation in the Treatment of Neoplasms of the Upper Respiratory Tract Am Jour Roentgenol 42 572 1939

16 Gans Oskar Histologie der Hautkrankheiten Berlin Julius Springer 1925 vol 1 198

16a Ghormley R K and Fairchild R D Surgical Treatment of Roentgen and Radium Dermatitis Surgery 7 737 1940 (Abstr) Year Book of Dermat and Syph 1940 p 517

17 Guldberg Gustav Experimental Researches on Precancerous Changes in the Skin and Skin Cancer Acta path et microbiol Scandin Supp 8 1931 p 247

18 Halberstaedter Ludwig Allgemeine biologische und schadigende Wirkungen der Rontgenstrahlen *in* Jadassohn Joseph Handbuch der Haut- und Geschlechtskrankheiten Berlin Julius Springer 1929 vol 5 pt 2 p 417

19 Harris Milo Leddy E T and Sheard Charles The Spectrophotometric Analysis of the Color of the Skin Following Irradiation by Roentgen Rays Radiology 19 233 1932

20 Herxheimer Karl and Uhlmann Erich Ueber die Wirkung der Grenzstrahlen auf die Haut Histologische Untersuchungen Arch f Dermat u Syph 157 407 1929

21 Jorstad L H and Lane C W Gross and Microscopic Changes in the Skin Produced by X Rays and by Lipoid Solvents Arch Dermat and Syph 19 954 1929

22 Kuznitzky E and Guhrauer H Radioaktive Substanzen I Radium und Mesothorium *in* Jadassohn Joseph Handbuch der Haut- und Geschlechtskrankheiten Berlin Julius Springer 1929 vol 5 pt 2 p 532

23 Kuznitzky E and Jacoby H Radioaktive Substanzen II Thorium X *in* Jadassohn Joseph Handbuch der Haut und Geschlechtskrankheiten Berlin Julius Springer 1929 vol 5 pt 2 p 629

24 Kyrle Josef Vorlesungen uber Histobiologie der menschlichen Haut und ihrer Erkrankungen Berlin Julius Springer 1925–1927 vol 1 p 141

24a Leddy E T and Riggs F J Radiodermatitis Among Physicians Am Jour Roentgenol 45 696 1941

25 Lieber G D Physikalisch chemische Wirkung der Rontgenstrahlen im Organismus IV Strahlentherapie 29 139 1928

26 LOMHOLT, SVEND: On the Employment of Radio-Active Matter in Solution, Acta radiologica, 2, 437, 1923–1924.
27. MACKEE, G. M., and ANDREWS G. C.: Roentgen Dermatitis and Radium Dermatitis: A Comparison, Arch. Dermat. and Syph., 4, 213, 1921.
28. MACNEAL, W. J., and WILLIS, G. S.: A Skin Cancer Following Exposure to Radium, Jour. Am. Med. Assn., 80, 466 1923
29 MAXIMOW, A. A.: Studies on the Changes Produced by Roentgen Rays in Inflamed Connective Tissue, Jour. Exper Med., 37, 319, 1923
30 MCCARTHY, LEE: Histopathology of Skin Diseases, St Louis The C V. Mosby Company, 1931, p. 513.
31 MICHAEL, J. C.: The Pathology of Chronic Radiodermatitis, Texas State Jour. Med., 26, 710, 1931.
32. MIESCHER, G.: Das Problem des Lichtschutzes und der Lichtgewöhnung, Strahlentherapie, 35, 403, 1930.
33 ———— Die Histologie der akuten Röntgendermatitis (Röntgenerythem) (mit besonderer Berücksichtigung der Teilungsvorgänge), Arch. f. Dermat u. Syph. 148, 540, 1924–1925
34. ———— Die Schutzfunktionen der Haut gegenüber Lichtstrahlen, Strahlentherapie 39, 601, 1930–1931.
35 MIESCHER, G.: Röntgenbiologie der gesunden und kranken Haut, Strahlentherapie, 27, 237, 1927.
36. ———— Untersuchungen über die Bedeutung des Pigments für den UV-Lichtschutz der Haut, Strahlentherapie, 45, 201, 1932.
37. MIESCHER, G., HARDMEYER, E., and GUGGENHEIM, L.: Ueber die Wirkung des weissen und infraroten Lichtes auf die Haut, Arch. f. Dermat u. Syph., 174, 445 1936.
38, 39. MILBRADT, WILHELM: Der Einfluss der Grenzstrahlen auf die Haut (Histologische und Histochemische Versuche), Dermat. Wchnschr., 102, 701, 732, 1936
40. ———— Der Einfluss der Grenzstrahlen auf die Haut Chemische Untersuchen, Dermat. Wchnschr., 103 918, 959, 1936
41. ———— Der Einfluss der Grenzstrahlen auf die Haut. (Physikalische und physikalisch-Chemische Untersuchungen). Dermat Wchnschr., 103, 1149, 1181, 1936. Abstract, *in* Wise, Fred. and Sulzberger, Marion, B., The Year Book of Dermat. and Syph., Chicago, The Year Book Publishers, 1936 p 482.
42. ————Experimentelle Untersuchungen zur Frage der Bedeutung des H-Vitamins für die menschliche Pathologie, Dermat. Wchnschr., 103, 1376 1402, 1936
42a. MONTGOMERY, HAMILTON and HILL, W. R.: Lichen Sclerosus et Atrophicus, Arch. Dermat. and Syph., 42, 755, 1940.
42b. MONTGOMERY, HAMILTON and SULLIVAN, R. R.: Acrodermatitis Atrophicans Chronica, Arch. Dermat. and Syph., 51, 32, 1945.
43. POHLE, E. A.: Studies of the Roentgen Erythema of the Human Skin. I. Skin Capillary Changes After Exposure to Unfiltered Radiation: Radiology, 6, 236, 1926
44. ———— Studies of the Roentgen Erythema of the Human Skin. II. Skin Capillary Changes after Exposure to Filtered Roentgen Rays and to Ultra-Violet Radiation, Radiology, 8, 155, 1927.
45 POHLE, E. A. and BUNTING, C. H.: Skin Reactions Following Exposure to Roentgen Rays: I. A Comparison of the Effect of Two Different Wave Lengths on the Skin of Rats, Radiology, 13, 495, 1929.
46. ———— Skin Reactions Following Exposure to Roentgen Rays: II. A Study of the Effect of Graded Doses of Two Different Wave Lengths on the Skin of Rats, Radiology, 15 647, 1930.
47. ROST, G. A.: Ueber der biologische Wirkung der Röntgenstrahlen auf die gesunde und kranke Haut, Strahlentherapie, 44, 521, 1932. Abstr. in Wise, Fred, and Sulzberger, Marion B., The Year Book of Dermat. and Syph., Chicago, The Year Book Publishers, 1933 p. 302.
48. ———— Experimentelle Untersuchungen über die biologische Wirkung von Röntgenstrahlen verschiedener Qualität auf die Haut von Mensch und Tier, Strahlentherapie, 6, 239 1915.
49 ROST, G. A., and KELLER, P.: Die Wirkungen des Lichtes auf die gesunde und kranke Haut, in Jadassohn, Joseph Handbuch der Haut- und Geschlechtskrankheiten, Berlin, Julius Springer, 1929, vol. 5, Pt. 2, p. 1.
50. ROTHMANN, H. G.: Zur Kenntnis der Histologie des Grenzstrahlenerythems, Strahlentherapie, 27, 518, 1927.

51 SAUNDERS T S A Study of the Late Manifestations of Roentgen and Radium Injuries of the Skin Thesis University of Minnesota

52 SAUNDERS T S and MONTGOMERY HAMILTON Chronic Roentgen and Radium Dermatitis Jour Am Med Assn 110 23 1938

53 SCHÜRCH O Studien uber Praecancerosen mit besonderer Berucksichtigung des experimentellen Rontgencarcinoms Ztschr f Krebsforsch 33 1 1930

54 WOLBACH S B A Summary of the Effects of Repeated Roentgen Ray Exposures Upon the Human Skin Antecedent to the Formation of Carcinoma Am Jour Roentgenol 13 139 1925

55 ———— The Pathological Histology of Chronic X Ray Dermatitis and Early X Ray Carcinoma Jour Med Res 21 415 1909

56 ZURHELLE E Ueber den Einfluss von Radiumstrahlen auf die Reaktionsfahigkeit der Haut Dermat Ztschr 72 129 1935

57 ———— Ueber den wellenformigen Ablauf des Radiumerythems sowie uber eine paradoxe Blasenreaktion auf Radium am Kamm und Kehllappen des Hahnes infolge Kollagenveranderung Strahlentherapie 57 473 1936

CHAPTER XXIV.

IDIOSYNCRASY.

As applied to radiation, idiosyncrasy means an inherent hyper- or hyposusceptibility to radiation—a personal, inbred peculiarity for which there is no explanation and which is never acquired. This peculiarity should not disappear nor fluctuate.

The history of this subject is interesting but it is of little practical importance today. Those who desire a dissertation and complete literary review of the subject are referred to previous editions of this book. Only a brief summary will be given here.

For many years there was a controversy as to whether or not idiosyncrasy to *x*-rays and radium existed. In 1911, Arcelin, in an endeavor to obtain a representative opinion, questioned thirteen leading European roentgenologists. Seven held that idiosyncrasy did exist; six expressed the opposite opinion.

In 1908 the senior author obtained the opinion of the leading American roentgenologists and dermatologists. The result was an equally divided opinion. In 1920 the majority opinion was against idiosyncrasy, but the vote was still divided. In 1930 it was difficult to find any leading roentgenologist or dermatologist who admitted true major idiosyncrasy.

The use of the term idiosyncrasy has decreased in about direct proportion to improvement in technic and knowledge. There may still be a few physicians who believe that major idiosyncrasy is a fact. The modern consensus is that while it may exist it is extremely rare.

During the past two or more decades members of our organization have epilated the heads of several thousand children afflicted with tinea capitis In spite of the exacting technic and the necessarily large dose, there have been no examples of idiosyncrasy. This experience coincides with that of others, even those who employ a considerably larger epilating dose. Occasionally incomplete defluvium is reported, but such result is probably caused by insufficient dosage rather than idiosyncrasy. Inadequate dosage may be caused by a head that is larger than average, age of the child, incorrect calibration of apparatus and other technical factors

For many years large accurately estimated doses of *x*-rays and radium have been administered to innumerable cases of cancer by experts who have not encountered unexpected acute reactions.

Until proved to the contrary, it may be assumed that minor degrees of idiosyncrasy are fairly common. Severe and mild examples of

xeroderma pigmentosum and farmers' skin seem to depend upon both inherent susceptibility and the amount of exposure to the sun. Chronic radiodermatitis resembles these diseases. Some persons apparently develop "x-ray skin" more readily than others. This difference may represent idiosyncrasy, but it is difficult to determine accurately whether these variations are caused by technical differences or by intrinsic characteristics of the individual. At the moment the evidence is in favor of idiosyncrasy.

MacKee and Fller tested with unfiltered x-rays 210 unselected persons. The doses employed in each case were 75 r, 150 r and 225 r. The test areas one inch square, were on the inner surface of the thigh or the flexor surface of the forearm. Grounded lead rubber was used for protection. No cases of "electric erythema" were encountered and there were no delayed reactions. This work was done in 1926 when technic was not so accurate and knowledge not so great as now. It was difficult to distinguish between faint erythema and faint pigmentation. We hope soon to report the results of similar tests made under modern conditions and more accurate controls. The results of the tests by MacKee and Fller are shown in the following table.

REACTIONS TO UNFILTERED RAYS[1]

Complexion	No. of cases	Erythema Dose in roentgens			Pigmentation Dose in skin units		
		75	150	225	75	150	225
Dark skin males and females	162	7	20	36	82	90	90
		4%	12%	22%	51%	56%	56%
Fair skin males and females	48	4	11	18	15	16	19
		8%	23%	37%	31%	33%	39%
Totals	210	11	31	54	97	106	109
		5%	15%	25%	46%	50%	51%

[1] The percentages are approximate.

Desjardins calls attention to a group of persons whose skin and subcutaneous tissues are unusually sensitive to roentgen rays. Anthropologically, these persons belong in Sheldon's endomorphic group and according to Desjardins can be recognized almost at a glance by the following physical characteristics—we quote Desjardins:

"The body has a rounded contour, that is, the lateral and anteroposterior diameters of the trunk are approximately equal. The bony framework and musculature are not developed as much as in individuals of the ectomorphic or mesomorphic type. The limbs are usually short and tapering; the hands and feet are small and the head is round. Not only is the contour of the trunk rounded but the extremities also are smoothly rounded and the muscles do not stand out in prominent bulges. Arms, thighs and legs are beautifully curved. In male individuals, especially at ages between twenty and forty years, the contours of the trunk and extremities and the texture and appearance of the skin often suggest those of the female. Still more

significant is the character of the skin and subcutaneous tissues. The skin has a smooth and fine texture, has the tone of fresh, soft rubber, and the hair is relatively thin or scanty, even on the scalp. Moreover, the skin and subcutaneous tissues together have the appearance and give the sensation of a firm, rubbery plumpness. In this group the sexes are about equally represented.

"The first step in recognizing these individuals is a good knowledge of the general appearance and conformation of the body, its compact, rounded, and attractive shape as a whole as well as in its different parts. The reader must not infer that all individuals with a body conformation of endomorphic type exhibit this feature to the same degree, far from it. The degree of endomorphism, in fact, varies with each individual. This feature is more prominent in some individuals than in others, and many gradations exist between this group and the two other groups of Sheldon's classification.

"The other and most important feature from the standpoint of sensitiveness to roentgen rays is the smooth, clear or semitranslucent appearance of the skin and its exceptional tone, as if a certain proportion of the best quality of rubber entered into its composition. It is a skin which is pleasant to look upon and to touch. The subcutaneous tissue also has an unusually firm and rubbery consistency, so that, when it is taken between the fingers and thumb, it has an unusual resiliency. The relative proportion of these features is a measure of radiosensitiveness in comparison with other persons.

"Once the ability to recognize this type of person beforehand has been acquired, the exceptional sensitiveness of the skin and subcutaneous tissues should always be kept in mind"

KNOWN CAUSES FOR TOLERANCE VARIATIONS.

It is well known that the skin of various persons and even that of the same individual will react differently under changed conditions These various factors will now be discussed separately.

Age.—The skin of any given part of an aged individual is definitely less sensitive than that of an infant There is also a noticeable difference between adults and children

Sex—The skin of females is perhaps slightly more sensitive than that of males

Texture.—A thin, fine skin is likely to be a little more susceptible than is a thick, coarse skin

Anthropologic Types.—This cause for lower tolerance is discussed elsewhere in this chapter.

Circulation.—A skin that is pale or anemic will react less readily than one that possesses a good circulation The most sensitive skin in this respect is one that is hyperemic or congested

Simpson obtained reactions in the skin of the anterior neck in women who had been applying ice for the relief of hyperthyroidism The

same patients, without the ice applications, failed to react. Cold applications produce localized anemia, and an anemic skin will tolerate comparatively large amounts of irradiation, while hyperemic skin is comparatively supersensitive. It is possible, therefore, that it was the congestion subsequent to ice application that produced the hypersensitiveness in Simpson's patients. Codman mentions cutaneous vasomotor irritability and congestion or hyperemia resulting from such applications as the high frequency spark, as causes for lessened resistance to irradiation. Sunburn, ultraviolet radiation, heat, solid carbon dioxide and various other physical agents may effect a temporary hypersusceptibility. Heidingsfeld found the skin in a case of dermatitis hiemalis abnormally sensitive.

Auer and Witherbee, working with rabbits, increased the resistance of the tissues to destructive doses of x rays by sensitizing the animals to a foreign protein (horse serum). Hektoen, working with dogs, made a somewhat similar observation. The inference is that the anaphylactic antibody anchored to the tissue cell increases the resistance of the cell to destructive doses. Control animals and sensitized-reinjected animals, the latter having antibodies in the circulating blood, were considerably more susceptible to roentgenization.

Color.—Blonds are usually more susceptible to irradiation than are brunets. The Negro skin is the most resistant.

Location.—Topographically there is a pronounced variation in susceptibility. Insofar as a visible reaction is concerned the least sensitive part of the body seems to be the scalp. The face is probably the most sensitive part. The extensor surfaces are more resistant than are the flexor surfaces. The flexures are very sensitive. There are important exceptions to these rules. The thin skin over the extensor surfaces of the articulations reacts more readily than does that of the immediate vicinity. The palms and soles, on account of the thickened horny layer, are less sensitive than such flexures as the anterior neck and the axillæ. The mucous membranes are perhaps more sensitive than the normal skin.

Irritants.—Irritating and stimulating chemicals applied to the skin before, during or shortly after irradiation, may substantially increase the effect. Such chemicals as iodine, chrysarobin, sulphur, mercury, oil of cade, pyrogallic acid, salicylic acid, iodoform, etc., if employed in strength (3 per cent or more, especially in ointments) and at about the time of irradiation, may create a hypersusceptibility of a high degree. Susceptibility caused by local applications will disappear in from one to four weeks, depending upon the strength and character of the application and the amount of reaction provoked. Hypersusceptibility will prevail during a chemical dermatitis and for a week or two subsequent to its complete disappearance. If no visible reaction follows a chemical application the skin will react normally to irradiation in a week or two. If irritating chemicals have been applied to the skin for a long period but without visible reaction, the skin is likely to

be hypersensitive for at least two weeks after the local applications have been discontinued. Solutions and especially ointments containing even small quantities of irritants, if employed at the time of irradiation, are likely to increase the effect.

After irradiation the skin is hypersensitive to irritants, the degree and duration depending upon the amount of radiation applied. Skin that has reacted to irradiation is often sensitive for a month or two. Skin that has been subjected to irradiation without visible injury will tolerate irritants of mild to moderate strength in about a month. Even strong irritants may be tolerated at this time, but the skin is

FIG 123.—A third-degree radiodermatitis due to irritating applications applied during a first-degree reaction. Note separation of slough at edge of ulcer.

likely to remain rather sensitive to such agents for a variable time. Skin that has been permanently damaged by irradiation may never tolerate strong local remedies.

The ulcer shown in the accompanying illustration was caused in the following manner: A double erythema dose of filtered x-rays had been employed to areas of equal size on the flexor surface of the right forearm and of the right popliteal space. In each area then developed a first-degree reaction which subsided in two weeks. Six weeks later another dose of the same size was administered to each area. Again a first-degree reaction occurred in each area. The patient applied ointments containing lysol, balsam of Peru and scarlet R medicinal

to the popliteal area but not to the forearm The forearm reaction soon disappeared A third-degree ulcer developed in the popliteal space We have reported a number of examples of this kind

Attention is called to the fact that not only is the irradiated skin less resistant to irritation but strong irritation applied to such skin may result in injury that is clinically identical to radiodermatitis and which may affect *x*-ray sequelæ It is unusual for this loss of resistance to last more than a few months except where the skin has been badly injured

Skin that has been badly damaged by irradiation behaves much as does sailors skin and xeroderma pigmentosum The excessive dryness favors eczematization Ulceration is likely to follow traumatism and exposure to direct sunlight or to extreme cold

It is advisable to avoid any topical remedy that can be classed as *an irritant especially in ointment form, during x ray or radium treatment* If the dose has been large, it is advisable to avoid topical irritants entirely, not only during the treatment but for several weeks subsequently If the skin has been visibly injured (atrophy telangiectasis) it may or may not tolerate topical irritants In such instances caution is necessary It is a well-known fact that such skin is exceedingly sensitive to strong chemicals, surgical operations refrigeration, electrodesiccation etc

Skin that is being irradiated appears to tolerate moderately strong topical remedies, but such irritants are likely to increase the total result, the combined effect is reciprocal If one is applying 75 r each week and also, an irritating ointment, the biologic effect might be that obtained with 100 r or 150 r in the absence of a topical remedy

Strong topical remedies (lotions emulsions, pastes and ointments) may cause erythema dermatitis and exfoliation This not only adds to the effect of irradiation but it makes it difficult to determine whether the reaction is due to the chemical or to the radiation For instance, assume that 75 r are being applied each week to the face for the treatment of acne Assume, also, that lotio alba is being applied daily and that the skin becomes irritable Is the reaction due to the lotio alba, to the *x*-rays or both? Erythema or desquamation evoked by topical remedies may mask an *x* ray or radium reaction

Many physicians do not hesitate to use strong topical remedies, especially when employing small weekly doses of *x*-rays In fact some physicians are not yet convinced that a mild *x*-ray or radium reaction may be followed by undesirable sequelæ We have had experience to the contrary There is danger associated with *x*-ray and radium treatment and it seems inadvisable to take any risk in routine work We advise against the use of any remedy that may be called irritating or that is capable of effecting a visible reaction, while employing *x* rays or radium

Subsequent Irradiation —Skin that has been irradiated but not visibly injured does not appear to acquire a susceptibility to further irradiation providing that accumulation is avoided If the skin has

been injured as manifested by a reaction or by sequelæ, it is likely to be more readily affected by subsequent irradiation. This has been especially noted by Bergonié. The acquired "susceptibility" may be transient, persistent or permanent depending upon the amount of injury and the ability of the tissue to repair the damage.

Accumulation.—Experience has taught that it is not safe, when it is desirable to avoid cumulative effects, to repeat heavy treatments in less than four weeks The interval will depend partly upon the size of the dose and its immediate effect on the skin. A two- or three-week interval may do for a suberythema dose but from four to six weeks is required for erythema doses and a longer period if the reaction has been of the second degree. After the subsidence of a reaction the skin is likely to be hypersensitive for several weeks. One reason for longer intervals is to avoid the possibility of delayed reactions. While it is true that if the skin is going to react it will do so in less than two weeks, there are occasional instances when the reaction does not appear until the third, fourth and even the sixth week.

It has been shown by Kingery that the tissue loses 50 per cent of irradiation effect in three and a half days. It is reduced to 5 per cent on the fifteenth day and zero is reached about the end of the third week No exception to this rule was encountered This work does not include supersaturation with reaction where the tissues are injured beyond complete repair or where considerable time is required to overcome the damage.

Filtration —It seems to be the general belief that the skin is injured less by filtered rays than by unfiltered rays and that greater injury to the skin is caused by beta rays than by gamma rays. If we confine the discussion to the possibility of cutaneous injury this opinion, if not erroneous, is at least misleading. All rays—beta and gamma rays of radium, filtered or unfiltered rays—will severely and permanently injure the skin provided the amount is sufficiently large. In other words it is more a question of quantity than of quality (Chapters XIII and XXV).

Disease and Systemic Factors.—Certain diseases and conditions of the cutaneous envelope seem to make the skin more responsive to irradiation Lesions associated with cutaneous congestion appear to be more sensitive to irradiation than does the surrounding skin—eczema, psoriasis, rosacea, mycosis fungoides, etc This is especially true before acanthosis and hyperkeratosis or parakeratosis have developed In diseases such as keloid and xanthoma the pathologic skin does not appear to react more readily than normal skin. Lesions associated with a thickened horny layer tolerate large doses, such as the common wart, for instance. Certain organic and constitutional diseases, especially those affecting the vasomotor system, or the sympathetic nervous system such as hyperthyroidism, modify cutaneous tolerance.

Ellinger, working with rabbits, finds that injections of thyrocin

increase radiosensitivity while thyroidectomy reduces it Flaskamp notes changes of tolerance associated with the premenstrual state pregnancy and puberty

FLUCTUATION OF CUTANEOUS TOLERANCE

We have noticed variations of cutaneous tolerance in the same person at different times A person may react to a certain dose one time and may fail to react to the same quantity a year or so later This has been noted, also by others It is not a perplexing phenomenon as the degree of tolerance may depend on the general health, condition of the vasomotor system nervous system, cutaneous circulation the endocrines etc One rosacea patient reacted repeatedly to 75 r when she was highly nervous and in very poor general health A year later, when in excellent health she did not react to 225 r The patient had hyperthyroidism This calls attention to hypersensitiveness of the skin to x-rays in cases of endocrine disturbances

ALLERGY

Sensitization to ultraviolet radiation and to the wave lengths of the visible spectrum have been reported We have not seen evidence of allergy or sensitization to x-rays or radium and we have been unable to locate literary reference to such occurrence

Unusual Results — There are a number of peculiar effects produced by x rays and radium which are due possibly, to individual peculiarities There is the precocious reaction, an erythema that develops in a day or two and disappears in from one to three weeks without developing beyond a first-degree reaction Then there are the radioerythema perstans and the delayed reaction Some individuals freckle or tan as a result of very minute doses while others do not do so even when the skin is made to react Following a reaction some dark skins may be depigmented Telangiectasia develops more readily in some skins than in others The same is true relative to other sequelae such as atrophy and keratoses

After an epilating dose applied to the scalp the defluvium occurs ordinarily in the third week and the hair begins to grow again in the third month It generally grows slowly steadily and equally over the entire scalp and, as a rule is of the same color texture and general character as the original hair The exceptions are as follows The hair may fall out in two weeks or not until the fourth week It may begin to regrow in six weeks or not until the sixth month The growth may be exceedingly vigorous or equally sluggish It may grow more rapidly in some areas than in others The new hair may be curly while the original hair was straight or *vice versa* The new hair may be either lighter or darker than the original it may be coarser or finer Some of these phenomena may be explained by variations in dosage

or by the effect of the disease, but individual peculiarities cannot be excluded in all of them.

In the heads of children there does not appear to be much variation in the dose required for epilation. In adults, however, it is not infrequent to encounter a fairly wide variation. We have seen depilation of scalp hair in an adult follow the application of 225 r. It usually requires at least 300 r for this purpose. In one instance (a case of favus) it required 600 r to cause the hair to fall. There was no erythema of the scalp which, incidentally, had been considerably altered by the disease. The skin of the back of this patient reacted normally to a dose of 300 r. The hair follicles may be hypersensitive when affected by disease It has been noted that the diseased hairs in tinea capitis depilate more readily than do the normal hairs Kienbock and Meyer have noted this phenomenon, especially in psoriasis The former obtained depilation of scalp hair in a case of psoriasis as a result of the administration of 2¼ X (less than half the epilating dose) His interpretation is hypersensitiveness of diseased follicles and not idiosyncrasy.

Radium —Regarding idiosyncrasy it is our experience and opinion that the same statements made relative to the *x*-rays answer also for radium. In the past, severe radium reactions were not so common as those associated with the administration of *x*-rays because radium was not in common use and because the technic was comparatively simple and, therefore, more accurate. The radium reactions of recent years have been caused to a large extent by inexperience with the more complicated modern technic (radon), by poor judgment, or by the various causes of and reasons for acquired hypersensitiveness enumerated in this chapter

BIBLIOGRAPHY

Arcelin, F Existe-t-il en radiothérapie des idiosyncrasies spontanées ou acquises? Arch d'élect med, **19**, 37, 1911

Auer, J, and Witherbee, W D Reaction of Normal Skin to Destructive Doses of Roentgen Ray, Jour Am Med Assn, **76**, 301, 1921

Bergonié, J Protection illusoire contre les rayons X chez les médecins déjà frappés, anaphylaxie physique ou indirecte, Compt rend Acad d sc, **162**, 613, 1916

Codman, E A A Study of the Cases of Accidental *X*-Ray Burns Hitherto Recorded, Philadelphia Med Jour, **9**, 438, 1902

Colwell, H A, and Russ, S Radium, *X*-Rays and the Living Cell, with Physical Introduction, London, G Bell & Sons, 1915, p 287

Desjardins, A U A Group of Persons Whose Skin and Subcutaneous Tissues Are Unusually Sensitive to Roentgen Rays, Am Jour Roentgenol and Radium Therapy, **50**, 636, 1943

Ellinger, F Untersuchungen uber die Hautwirkungen von Rontgenstrahlen am Kaninchen, Strahlentherapie, **43**, 358, 1932, **47**, 517, 1933, **47**, 727, 1933, **48**, 97, 1943

——— The Biologic Fundamentals of Radiation Therapy, New York, Interscience Publishers, 1941

Flaskamp, W Ueber Rontgenschaden und Schaden durch radioaktive Substanzen, Strahlentherapie, Sonderband xii, 1930

Haas, L Ueber die Rontgenhypersensibilitat der Haut, besonders bei innersekretorischen Storungen, Deutsch med Wchnschr, **48**, 1134, 1922

HEIDINGSFELD M L Epidermolysis Bullosa (Factitia) Traumatic X Ray Bullous Dermatitis Cincin Lancet Clinic (n s) 49 116 1902
HEKTOEN L Further Studies on the Effects of the Roentgen Ray on Antibody Production Jour Infect Dis 22 28 1918
KIENBOCK R Ueberempfindlichkeit der Haarpapillen für Rontgenlicht bei Psoriasis Fortschr a d Geb d Röntgenstrahlen 22 591 1914–1915
MACKEE G M and ELLER J J Variations of Cutaneous Toleration for Roentgen Rays Jour Am Med Assn 87 1533 1926
SCHULTZ F X Ray Treatment of Skin Diseases New York Rebman Company 1912 p 50
SIMPSON C A The Sensitizing Effect of Cold on Roentgenized Surfaces Am Jour Roentgenol 3 485 1916
WICKHAM L and DEGRAIS P Radiumtherapy London Cassell & Co 1910 p 92

CHAPTER XXV.

GENERAL THERAPEUTIC CONSIDERATIONS.

DOSAGE.

Indications for the therapeutic use of the x-rays and the radioactive substances have undergone a great change during the past two decades Years ago, these agents constituted the best or the only successful therapeutic method for many of the dermatoses. Now, many if not most of the cutaneous diseases respond better to modern conventional dermatologic management than to irradiation. This is scientific medical progress, the result of creative research, and is to be encouraged. Also, years ago, one did not hesitate to administer large quantities of x-rays or radium to benign lesions that refused to respond favorably to small quantities. The disfiguring and serious sequelæ of excessive irradiation are now well known; also the total amount of radiation that the skin can tolerate and the amount indicated for each dermatosis are equally well known. For these reasons most adequately trained dermatologists employ x-rays or radium only in safe dosage and only when there is no successful medicinal therapy for the particular disease, or because such treatment has failed Of course, there are exceptions. It is difficult to teach judgment, some persons are incapable of guidance. Therefore we still encounter too many cases of x-ray and radium injuries.

The object of therapeutic applications of x-rays and radium is to cure or relieve objective and subjective symptoms If radiation is applied to a disease in which such treatment is contraindicated, thus making its symptoms worse, or because of excessive dosage an undesirable and even dangerous sequela is substituted for a harmless lesion, then the main object of roentgen therapy and radium therapy has been defeated.

Of the cutaneous diseases that are amenable to irradiation, the majority can be cured or improved by a quantity of radiation that will have no injurious effect on the skin With the exception of the malignant diseases, where large quantities are necessary to save life, an attempt should be made to keep the dose within the amount that will prevent a reaction and the quantity that might avoid sequelæ. If the operator is in doubt it is advisable to request a consultation and a division of responsibility. The main points to be emphasized here are: First, prolonged treatment should be avoided. If a disease, usually amenable to a prescribed amount of irradiation over a given amount of time, fails to respond favorably to such treatment, it is advisable to discontinue the exposures. It is much better to lose a patient on account of failure to cure than it is to effect a cure at the

expense of cosmetic disfigurement The disease might be cured in some other way, the cosmetic defect from irradiation may be permanent It is well to bear in mind constantly that repeated exposures over a long period of time, even without the advent of erythema may *lead to visible cutaneous atrophy and even to keratoses*

The second point is that excessive dosage is to be scrupulously avoided Heavy dosage is indicated in epithelioma as already stated, but even here it is inadvisable to effect more than a first-degree reaction or, at the most a mild second-degree reaction In all other diseases we urge the avoidance of even a mild first-degree reaction

In many cutaneous diseases—keloid, acne vulgaris circumscribed neurodermatitis inveterate and nummular psoriasis, chronic squamous eczema etc —a single dose sufficient to effect an erythema or a few small doses so spaced that an erythema is the immediate result, will suffice to effect a prompt cure Severe examples of acne indurata will often undergo complete involution as a result of a mild first-degree radiodermatitis Such treatment however, is not warranted It cannot be too often stated nor too forcibly emphasized that a single erythematous reaction even when exceedingly mild will in some persons be followed by wrinkling and telangiectasia The slogan for radiologists, whether employing radium or x-rays should be never to effect even a slight first-degree reaction if it can possibly be avoided or unless the necessity for such reaction is a requisite for the cure of a dangerous disease

Roentgen dosage is expressed in many ways In previous chapters we have described explained and discussed the roentgen, the threshold dose and the erythema dose, how they are determined the advantages and disadvantages There is as yet no universally accepted dose standard except the roentgen which is the standard for intensity Hence we hear of the roentgen the threshold dose erythema dose epilating dose, full dose, skin tolerance dose saturation dose reaction dose intensive dose, massive dose fractionation dose suberythema dose and so on

Erythema Dose—The amount of x-rays that will usually effect faint erythema on a sensitive part of the body of adolescents or young adults—face anterior neck axillæ flexor surface of arms and thighs and abdomen—in an area 1 inch square is called the erythema dose The amount of radiation required to produce a mild reaction in the skin will differ somewhat in different individuals The so called erythema dose will not always provoke an erythema even on sensitive parts *Again there are persons whose skin may react slightly to three-quarters* or even one half this quantity As explained in previous chapters there are many reasons why the reaction differs in various persons—age location disease, size of area etc The erythema dose is simply an average standard for which corrections must be made every time a treatment is given For unfiltered radiation most American dermatologists use 300 r for the erythema and epilating dose This dose is

the same for any apparatus after the equipment has been checked and standardized, and the technic established. A few dermatologists and many roentgenologists standardize the epilating and erythema dose at 400 r and even higher. We recommend 300 r for the erythema dose for adults and for the epilating dose for children's scalps when using low voltage unfiltered *x*-rays.

In recording doses or in giving information relative to treatment, the operator should mention the essential details of the technic—number of roentgens, milliamperage, voltage (wave length or half-value layer, if possible), time, distance, filtered or unfiltered and, if filtered, the filtering material and its thickness. It is advisable also to mention the type of apparatus employed (thermionic or mechanical or shockproof). Unless one operator is familiar with the technic employed by another operator, it will not suffice to say simply that an erythema dose was administered. There would be too much possibility of error or misunderstanding. It is often necessary to refer a patient to another city for treatment. In such instances it is advisable to give at least the details as follows:

April 25, 1940: 300 r; Ma., 2; Kv., 90; T., 3 min.; D., 8 in.; unfiltered; valve tube rectification. Also information relative to number of treatments, time between treatments, effect of previous treatments, suggestions as to further treatment, etc.

When employing radium it is advisable to mention the type, size and strength of the applicator, exposure time, distance from the surface and thickness of the filter as well as the material of which it is composed and the distribution of the radium or radon containers.

REST INTERVALS BETWEEN TREATMENTS.

Fractionated treatment can be given in various ways. For a malignant neoplasm it is customary to administer an erythema or larger dose daily or every second day for a total of from 1200 to 3000 and more roentgens (unfiltered) and from 2400 to 6000 or 8000 roentgens (filtered), depending upon the degree of malignancy, location and size of lesion, the condition of the tumor bed, age of patient, voltage, filtration, etc. After such treatment one to several months are allowed to elapse before more treatment is given, if additional treatment is advisable or necessary.

The routine for most skin diseases consists of administering one-quarter the erythema dose (75 r unfiltered) once weekly for from four or six to the arbitrary maximum of 16 treatments, depending, of course, upon the disease. This routine is for adolescents and adults. Half or less of this dose is used for children.

Large single doses are sometimes used for a number of diseases, from 150 r to 300 r or even several times the erythema dose (unfiltered). When half the erythema dose (150 r) is applied it may be repeated in two weeks always depending upon the disease, size of lesion, etc.

Larger doses (300 r) are given at intervals of a month or two After still larger doses it is customary to allow several months to elapse *before irradiating again assuming that more treatment is desirable*

FRACTIONATED VERSUS LARGE SINGLE DOSES

As indicated in previous chapters, the biologic effect of x rays or radium depends upon the amount of radiation that is absorbed by the pathologic cells, also by the neighboring normal tissue The absorption and ionization are modified by and depend upon a number of factors, such as the time-intensity factor the size of the dose, time interval between treatment, etc , all of which are discussed in previous chapters

What concerns us here is the controversy relative to the result of a single large dose as compared with a considerably larger total dose given by the fractionated technic particularly for the treatment of malignant diseases Advocates of fractionation aver that a larger total dose can be administered without additional injury to normal tissue This agrees with the consensus They also believe that by keeping the diseased tissue in a state of lethal saturation for a week or longer, a larger number of young cells and cells about to divide are destroyed Advocates of the single large dose believe that such treatment accomplishes all that can be accomplished, that when a lethal dose is administered there will be no further cell division The results of each method are satisfactory but, at present, the fractionated technic is the more popular, partly because there is less strain on the patient and physician

In dermatology the fractionated technic is employed mostly for malignant neoplasms Large single doses are administered to small benign lesions such as warts, angiomas etc and weekly treatments of 75 r are used for most of the dermatoses that are amenable to x ray treatment

TREATMENT OF SMALL LESIONS

With the exception of malignant neoplasms, the normal skin around circumscribed lesions should be protected by a piece of lead foil or other suitable material Ordinarily a thickness of $\frac{1}{64}$ or $\frac{1}{32}$ inch of lead will provide adequate protection but when large doses are employed especially in the case of filtered radiation it is advisable to use several layers of lead foil A diaphragm is made by cutting out of the center of the foil a hole the exact size of the lesion The shield should be of sufficient size to intercept all the oblique rays that pass through the diaphragm of the tube holder

Care should be taken to center the anode directly over the center of the lesion and to see that no unprotected part of the body is closer than the center of the lesion

There are occasions when it is desirable to apply intensive radiation to a group of very small lesions between which there is normal skin. The normal skin in such instances can be protected by cutting holes, of the correct number, size and shape, in a piece of lead foil. Another method is to coat the skin with a 50 per cent bismuth, barium or zinc oxide paste. When employing these heavy elements (lead, zinc, bismuth, etc) for this purpose, the possible effect of "soft" secondary radiation must be considered. However, with the doses used in cutaneous roentgen therapy, no harm has resulted when employing these materials.

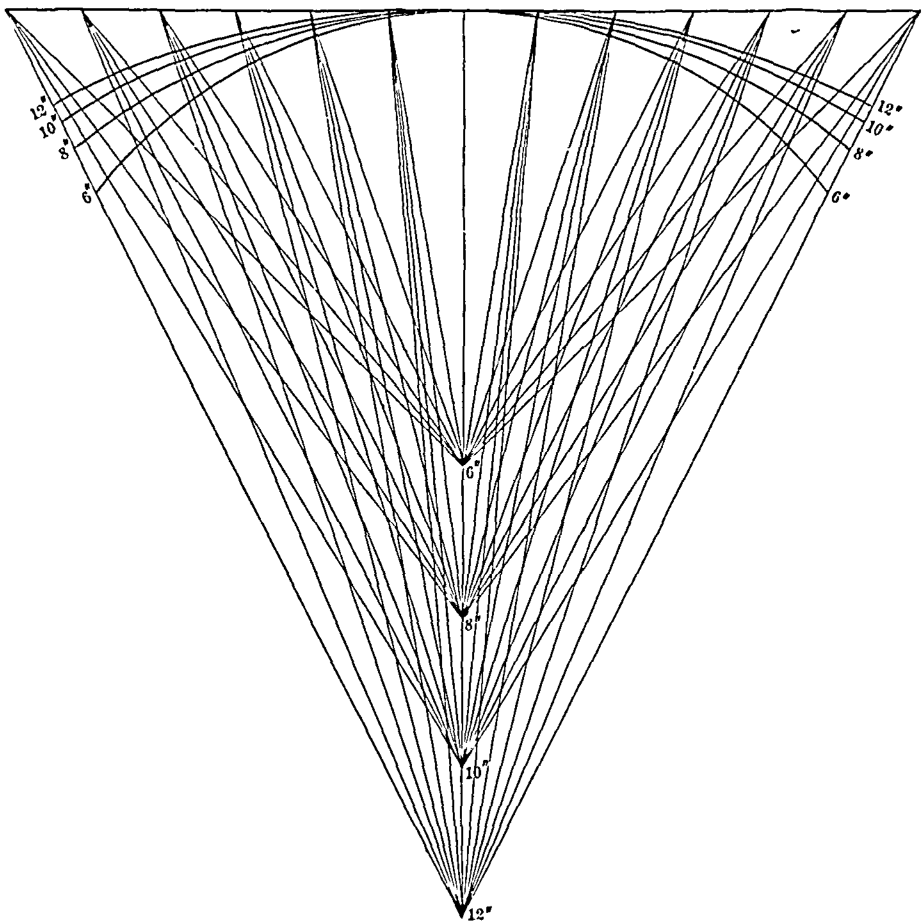


FIG 124 —Showing the spread of radiation with skin-target distance of 6, 8, 10 and 12 inches Shows the loss of intensity as the sine of angle of incidence or inversely as the square of the distance Shows also the degree of concavity necessary to equalize intensity over an extensive surface

DIRECT AND OBLIQUE RAYS.

There is a physical law that has received considerable attention by radiologists· Intensity varies (1) Inversely, as the square of the distance, (2) directly, as the sine of the angle of incidence For the

sake of simplicity the second way of expressing this law may be disregarded, as the first will cover all questions relating to the second The so-called direct rays are those that pass from the target straight to the lesion The so-called oblique rays strike the skin around the lesion and are less intense for the simple reason that they have to travel a greater distance Fig 124 shows the difference in the length of the direct and the oblique rays falling upon a flat surface and derived from minute points at distances of 6, 8 10 and 12 inches At first glance it would seem as though there might be an enormous difference in intensity at the periphery when comparing the 6- and 12-inch skin-focal distances As a matter of fact, the difference is not great With an 8-inch skin-focal distance the loss of intensity at 6 inches from the center of a flat surface is $\frac{1}{3}$ With a skin focal distance of 12 inches the loss is between $\frac{1}{3}$ and $\frac{1}{4}$ At a distance of 32 inches the loss is about $\frac{1}{16}$ At very short distances the difference is greater

As explained in previous chapters there is a difference in the intensity of oblique radiation and in the spreading of radiation obtained from some shockproof apparatus This is because the oblique rays pass through more of the intrinsic filter because of the shape of the portal and because of the size and shape of the focal spot and the angulation of the target It is expected that these faults will be corrected by the manufacturers In any case the operator should be familiar with all the characteristics of his apparatus

TREATMENT OF LARGE LESIONS ON FLAT SURFACES

It is customary to place the anode over the center of a large lesion and allow the rays to spread over the entire affected area As shown in the preceding paragraph a lesion 1 foot square will receive one-third less intensity at the periphery than at the center, with the usual working distance of 8 inches Individual lesions seldom have a diameter of more than 6 inches so that this loss of intensity is of no practical importance for flat surfaces or for lesions that are easily cured In epithelioma, however, it is essential that intensity be fairly uniform over the entire surface In this connection it might be well to state that oblique rays passing through a tumor of considerable thickness will be compelled to penetrate more tissue than will the direct rays, so that in addition to loss of intensity by distance there is also a loss caused by additional absorption

There are two ways in which intensity can be fairly equally distributed over a large flat surface First by increasing the skin-focal distance to at least 32 inches preferably 4 or 5 feet An increase in the length of the skin focal distance causes greater intensity at a given depth below the surface A long skin focal distance is advantageous, therefore in the treatment of large lesions and thick lesions The second method consists of dividing the lesion into two or more areas, each area is then given a separate treatment It is necessary to fit

the protecting material very accurately, so as to avoid overlapping of exposures or to leave parts of a lesion unexposed. It is customary to mark out the areas with a skin pencil and allow about $\frac{1}{4}$ inch between areas. It is presumed that this amount of tissue will be taken care of by the scattered and secondary rays. The lead foil, or other protecting material, should be firmly fastened to the skin by adhesive plaster or weights.

TREATMENT OF CONVEX AND CONCAVE SURFACES.

Irradiation of convex and concave lesions of fairly large dimensions is associated with considerable difficulty. The method of applying radium, in the shape of flexible applicators, radium packs, etc., is described in Chapter VII. In *x*-ray work a slight concavity may be just sufficient to overcome the loss of intensity at the periphery. Or, the surface may be so concave that the periphery of the lesion or certain normal parts may be actually closer to the anode than is the center of the lesion. It is these depressed and crateriform areas that stimulate the resourcefulness of the technician As examples of such surfaces may be mentioned the inner canthus and the anal region. These surfaces can be flattened out to some extent by pressure or by spreading the tissues apart If this cannot be accomplished, a reasonable equalization of intensity can be obtained by shielding all but the floor of the concavity and applying from one-quarter to one-half the desired dose, the amount depending upon the slope of the walls of the concave surface. The shield is then removed and the exposure continued until the full dose has been administered. The curved lines in Fig. 165 indicate the degree of concavity required to equalize intensity over a surface of any size.

Convex surfaces are troublesome because, with the anode centered over the center of a lesion, the distance from the source of radiation to the periphery of the lesion may be considerably increased as compared with a flat surface of the same size. Indeed, the surface may be so convex that the periphery of the lesion may receive no radiation at all. In such instances it may be necessary to make multiple exposures Take, for instance, a lesion occupying the anterior and lateral surfaces of the forearm. Three exposures are required—one for the anterior and one for each lateral surface. If each exposure is at right angles to the other no protection is required—the rays from each are allowed to overlap.

ROENTGENIZATION OF ENTIRE BODY.

Not infrequently it is necessary to apply the *x*-rays to practically the entire body. The requisites are (1) Not to lower the lymphocytic count, (2) not to cause too-rapid involution of lesions, (3) reasonably uniform distribution of intensity. Not only must the dose be small, but only a small section of the body should be exposed on any one day It is customary to divide the body into from four to six

areas and to apply a dose to one area each day No section of the body is treated more than once a week The body surface may be divided somewhat as follows (it is assumed that the anode-skin distance is 8 inches)

1 *Head and Face* —This requires five exposures, the angles of incidence being the same as those used in the treatment of tinea capitis The face and neck are not shielded In fact, in generalized roentgenization no shield other than the regular tube shield is used Incidentally, the diaphragm of the tube shield must be large, or the tube will have to be placed at a considerable distance from the skin It is to be understood that the eyes, eyebrows, ovaries and testes are suitably protected or that the dose is to be too small to injure these parts

2 *Chest, Abdomen and Anterior Surfaces of the Arms, Forearms and Hands* —Four exposures The arms are held in contact with the trunk, on a level with the abdomen If the arms are long the hands will not be included in this section and will receive treatment when the thighs are exposed Exposures are made over each side of the chest, at the level of the nipples, and on each side of the abdomen about the level of the umbilicus It is important that the anode for each exposure be at least 12 inches from any other exposure

3 *Entire Back* —This includes the posterior surfaces of the arms *forearms and hands Four exposures are required as in the last* section

4 *Anterior Surfaces of the Thighs and Legs* —Six exposures are usually required—two for the anterior and posterior surfaces of the thighs, two for the anterior and posterior surfaces of the knees and two for the anterior and posterior surfaces of the legs It is well to state again that every exposure must be at least 12 inches from any other exposure Assume, for instance, that the operator is exposing the upper back In the case of a large man the anode may be placed over the scapulæ, or over the point of the shoulders In the case of a small woman the anode may be considerably to one side of the scapula and much radiation may be wasted Nevertheless, the exposures must be at least 12 inches apart

Many persons will not be able to tolerate this amount of treatment and furthermore it may be necessary to treat the lateral surfaces of the arms, thighs legs and trunk separately In universal eruptions it is therefore preferable to divide the cutaneous surface into six sections, begin with about 38 r unfiltered, make frequent blood counts and watch for constitutional symptoms

In a recent article Pascher and Kanee who have investigated the subject state that general body irradiation with unfiltered x-rays as used for generalized eruptions can injure the hematopoietic tissues They give the results of their research and a review of the literature In radiosensitive persons they find that leukopenia and hypochromic anemia often result when the entire body surface is exposed each week

to 75 r, the treatments being given three times weekly, approximately one-quarter of the body being exposed at each sitting, and the treatment continued for from three to six weeks. Recovery may not be complete before four or five months.

SYSTEMIC REACTIONS.

Years ago it was common to observe systemic and cutaneous reactions as complications of *x*-ray and radium treatment of skin diseases. The systemic reactions consisted of fever, anemia and more or less prostration Cutaneous reactions consisted of papular and scarletiniform pruritic eruptions. The cause was probably the too-intensive irradiation of pathologic tissue that is readily amenable to such treatment—mycosis fungoides, leukemia, psoriasis, etc.; or by too-vigorous generalized irradiation which may cause reactions through the destruction of lymphoid tissue. During the past two decades these various systemic and cutaneous reactions have been seldom encountered, presumably because of modern knowledge, technic and judgment. With one exception we have not seen a single instance of these untoward reactions for many years The exception is in the case of scalp ringworm. Occasionally, after the administration of an epilating dose to the entire scalp of a child affected with disseminated tinea capitis, a more or less generalized erythemato-papular rash occurs which may be accompanied by malaise for a day or two. Presumably the reaction is caused by destruction and absorption of cellular elements

Roentgen and Radium Sickness.—There is a type of systemic reaction which is commonly encountered subsequent to the administration of heavy, filtered doses of either *x*-rays or radium rays The reaction occurs within a few hours after the treatment and may last from a day to a week. It consists of varying degrees of anorexia, nausea, vomiting, headache, chills, fever and prostration. Pfahler, Béclère, Jones and Roth, Lang and others have studied such reactions carefully, but the cause has not been definitely determined nor is there any certain way to avoid them. Pfahler believes that the reaction is due to gases (ozone, etc.) produced by the effect of the high tension electricity on the air or, in the case of radium by ionization, and inhaled by the patient Lang is of the opinion that the effect is due to acidosis. Jones and Roth call attention to the fact that the reaction in question occurs subsequent only to irradiation of the abdomen and lower chest; that it is not observed when the vagus nerve does not fall in the field of treatment. These authors have observed different types of reactions when various parts of the body have been irradiated and conclude that the reaction is due to the direct effect of the radiation on human tissue. When the region of the salivary glands was irradiated they found alterations in the salivary secretion, taste and smell. When the gastric glands and vagus nerve were irradiated nausea and vomiting were the result. Ewing has made similar observa-

tions Beclere calls attention to the fact that nausea and vomiting may follow large amounts of radiation applied to the cervical and axillary regions, to any part of the abdomen (even as a result of radium in the vagina) and to the chest Such observations are in accord with the experience of most radiologists Beclere's conclusion is that the reaction in question is caused chiefly by the adulteration of the blood with toxic substances resulting from the disintegration of the pathologic or normal cellular elements destroyed by the radiation, also that there must be a direct action on the nerves

Schreiner and Stenstrom, in a critical summary of the assumed causes of roentgen intoxication, discussed the following causative theories

1 Gases produced by high voltage roentgen rays (ozone, nitric-acid fumes, etc), with good ventilation, not enough is left to account for sickness

2 An electric field surrounding the patient If tube and aerial are properly grounded there will not be an electric field Sickness is seen when grounding is perfect

3 Chemical changes which can be estimated Nitrogen output is increased, but sickness is not proportional to this change

4 General influences on the body Changes of cells in the body take place wherever rays are absorbed The body dose is roughly proportional to amount of sickness

5 Radiation of certain glands The adrenals are quite sensitive to radiation As a small dose over the adrenals will cause nausea they would probably react to an appreciable amount of scattered rays Nausea is also a common experience when the ovaries are irradiated

6 Nervous strain and psychic influences on the patient Nervous high-strung patients are more apt to be sick than robust individuals The maintaining of position and covering with lead rubber etc, give them a sensation of restraint

7 Destruction of intestinal mucosa Warren and Whipple claim that this is the main cause They also state that this takes place only if the intestines are in the roentgen-ray field This theory does not explain the cause of sickness when, for instance the breasts are irradiated So irradiation sickness is not explained on this basis alone

There is no doubt that several of these factors cooperate in causing radiation sickness

The amount of roentgen rays absorbed in the body can be used as a clinical guide in these sicknesses unless certain glands are irradiated

Zacherl found that in animals united parabiotically irradiation sufficient to produce toxemia in the irradiated animal also resulted in toxemia in the non-irradiated animal A brief leukocytosis was followed by a leukopenia and the body temperature became subnormal The phenomenon is similar to a protein shock and may be due to destruction of protein and liberation of the end products

Markovits believes that the sickness is caused by sodium chloride

deficiency. Waegner claims excellent results by administering a cholesterin-lecithin mixture as a prophylactic. The rationale is based on the discovery of cholesterin deficiency by Levy-Dorn and Burgheim. Mühlmann finds that the intravenous injection of grape sugar prevents roentgen sickness.

Richards has used nembutal with success. Smithers suggests vitamin B_1 and histaminase. Whitmore recommends thiamine hydrochloride, liver extract and calcium salts. Vitamin B_6 has been recommended. Young depends upon liver extract. There is considerable modern literature dealing with possible causes of radiation sickness. The majority of investigators agree that the cause is the breakdown of susceptible tissue elements, disturbed body metabolism, and resulting vitamin deficiency, but exactly what occurs is not yet known Also, it is generally agreed that liver extract is the best remedy.

LOCAL MEDICATION.

Large doses should not be administered to persons who have been applying stimulating or irritating applications to the affected part. Small doses are permissible but caution is advisable (see chapters on Radiodermatitis and Idiosyncrasy).

CROSS-FIRE TREATMENT.

It is often difficult, even with filtration and increase of skin-focal distance, to apply a sufficient amount of radiation to the deeper parts of a thick lesion or to a subcutaneous tumor without injury to the overlying tissues. Cross firing is the utilization of two or more ports of entry. Through each port is passed a skin-tolerance dose. The result is that a subcutaneous tumor receives the radiation, minus decrease of intensity by absorption and distance, from each port, but no one portion of the skin receives more than one exposure. The tumor receives, of course, the scattered and secondary radiation from the primary beam of radiation that passes through each portal. Assume an epithelioma involving the skin and deep tissues of the nose. Cross-fire treatment would consist of an x-ray treatment externally and a radium tube placed inside of the nose. A subcutaneous tumor of the thumb might be cross fired from four angles—anterior, lateral and posterior surfaces. Large cutaneous tumors that are considerably elevated may be cross fired by dividing the mass into several squares. Also, radium needles and radon seeds can be inserted into various parts of the growth (Chapter XVII)

ESTIMATION OF INTENSITY BELOW THE SURFACE.

Most of the diseases that are treated with x-rays and radium by the dermatologist are very superficial, therefore he is not particularly interested in the so-called depth dose. However, in many cutaneous

diseases, such as some of the malignancies hypertrophies benign new growths and other conditions estimation of intensity below the surface is important Methods of determining the dose at various depths, both with radium and x-rays, are described in detail in Chapters VII, IX and especially in Chapter XII

FILTRATION

The object of filtration is to remove the rays that are absorbed by the superficial tissues By suitable filtration the x-ray beam is made more homogeneous and, as with such radiation, there is less absorption by superficial tissue, there is a more uniform intensity throughout the deeper tissues Filtration is therefore, indicated in the treatment of subcutaneous tumors and nodules, such as erythema induratum, sarcoid, certain types of epithelioma and sarcoma tuberculous adenitis etc Also diseases in which the pathologic tissue is of considerable volume—keloid, epithelioma, etc

It has been said that filtered x-rays are advantageous in all but the most superficial dermatoses (Gunsett Regaud and Nogier and others) Many roentgenologists aver that filtration when employed in diseases of the appendages—acne vulgaris sycosis, hyperidrosis, etc —will effect the desired result with less injury to the normal skin than is the case with unfiltered rays The theory is that the appendages, being situated fairly deep in the true skin, should be exposed to radiation from which has been removed the wave lengths that will be entirely or mostly absorbed by the epidermis and superficial part of the derma With wave lengths ordinarily used in practice it is doubtful if there are many wave lengths that are completely stopped by the epidermis and papillary body Even in cases of radiodermatitis due to very long wave lengths the microscope shows the true skin injured to its full depth the active ulceration of the more superficial tissue being largely if not entirely due to vascular changes and not to the direct action of the radiation on the cellular element of the epidermis Certainly the x-rays from an ordinary roentgen bulb never effect the exceedingly superficial reactions that are caused by the secondary radiations from lead or those produced by the beta rays of radium The nearest approach to such superficial reactions is seen when an x ray tube is placed in contact with or within a few centimeters of the skin The so called grenz rays effect a very superficial reaction

As indicated in previous chapters, distance is an important factor when it is desired to obtain a more even distribution of intensity throughout several centimeters of tissue Of course the same theory holds true for a few millimeters of tissue as well as a few centimeters of tissue With the glass wall of the tube within a few millimeters of the skin there will be more absorption of radiation by the first few layers of tissue than when the tube is placed at the usual working distance of 8 or 10 inches

It cannot be denied that with filtered radiation there is a more equal distribution of intensity throughout the few millimeters of tissue comprising the normal derma, and that, theoretically at least, such radiation is indicated when it is desired to influence the appendages that lie in the middle or lower part of the true skin.

In practical work it is possible that a filter is preferable in all but the most superficial diseases, but no one has yet proved this to be the case. Let us apply the theory to some definite disease, hypertrichosis. In this condition it is necessary to effect a permanent loss of hair. To do this requires permanent atrophy of the hair follicles. Naturally one prefers to accomplish the desired result without visible injury to the skin as a whole. At first thought it would seem advisable to use filtered "hard" rays with the tube at a distance so as to avoid a relatively high absorption of radiation by the epidermis and upper derma. But this does not seem to give much, if any, better results in practice than do unfiltered rays with kilovoltage between 80 and 100. The explanation is possibly that with such thin tissue the difference in absorption for the first few layers is not very great for unfiltered and filtered radiation when the roentgen tube is at a distance of at least 8 inches and the kilovoltage is at least 80. More important, perhaps, is the fact that no matter what quality of radiation is used, the follicles must be destroyed. And, in spite of the fact that the hair follicles are more susceptible than is the surrounding connective tissue to the effect of radiation, when a sufficient amount of any quality of radiation has been absorbed by the follicles to effect their permanent destruction, the other structures show degenerative changes that will lead to sequelæ.

In our experience it has been difficult to ascertain the real value of filtration in diseases that affect only a few millimeters of tissue because the results have appeared to be the same with both filtered and unfiltered radiation. It is, of course, quite a different proposition when we are dealing with pathologic tissue of considerable depth or with subcutaneous diseases.

Experiments with filtered and unfiltered *x*-rays, in symmetrical superficial eruptions or in lesions of a size that permit one-half being exposed to filtered and the other half to unfiltered rays, seem to show that there is little if any difference in efficacy, providing the quantity is the same in each instance. This may not be true for all superficial diseases, but very little difference was noted in such diseases as mycosis fungoides, acne, psoriasis and eczema. If this work can be corroborated by others, it will tend to indicate that quality is for the most part less important than quantity in superficial therapeutic work.

Shockproof apparatus is rapidly replacing non-shockproof machines, and it is the apparatus of the future. Part of the outfit consists of an oil-immersed *x*-ray tube. The radiation passes through a thin layer of oil and a thin layer of some material such as aluminum. Unfiltered radiation cannot be obtained from an outfit of this kind.

It is our opinion that lightly filtered x-rays (0.25 mm aluminum, for example) are as efficacious in cutaneous diseases as are unfiltered x-rays. We have and are using both types of apparatus, our results are the same with each.

What has been said of the x-rays relative to filtration can be applied to radium but only in respect to the gamma rays. The beta rays are for the most part stopped by a few millimeters of human tissue. Furthermore, they are extremely active ionizers and exert a profound influence upon superficial tissues. When applying radium for deep effects it is essential that the beta rays be entirely eliminated. This can be accomplished by suitable filtration. Two or 3 mm of lead or from 1 to 1.5 mm of platinum will cut out all but the most penetrating gamma rays, thus making the radiation fairly homogeneous. The usual screen is 0.1 or 0.2 mm aluminum when it is desired to utilize beta rays. Such a screen eliminates the 'soft' beta rays. Otherwise it is customary to filter with 0.5 mm silver, 1 mm brass and 1 mm aluminum or with 0.5 mm platinum.

Unfiltered beta rays are reduced to about 6 per cent of their original intensity after passing through 1 cm of human tissue (Colwell and Russ). Two-tenths millimeter of aluminum will eliminate the "soft" beta rays and the very 'soft' gamma rays. By such screening and sufficient exposure it is possible to obtain a pronounced direct beta-ray effect to a depth of several millimeters. Normal skin ranges in thickness from 1 mm. to perhaps 5 mm. In disease this thickness varies from 0.25 to 4 cm. It is obvious, therefore, that the thickness of tissue is of considerable importance when beta rays are employed. It would seem advisable when employing radium to use always at least a very thin screen—0.1 mm aluminum—even for the treatment of superficial conditions. (For further details consult Chapters VII, VIII, X and XVII.)

Thus far we have not been favorably impressed with results obtained with radon ointment, radium element pads and thorium X.

TREATMENT OF THICK LESIONS AND DEEP-SEATED LESIONS

For detailed information relative to the treatment of thick and deep-seated lesions, the reader is referred to the preceding paragraphs of this chapter—also to preceding chapters. It is obvious that there are several ways in which intensity can be increased in the deeper tissues without subjecting the superficial tissues to increased radiation—filtration, cross fire, increase of distance, dehematization and implants.

DISTANCE

The operator should take note of the important fact that errors in dosage resulting from errors made in measuring distance are far more serious for small distances than for great distances. For example, if

the dose at 6 inches is taken as a unit and the operator makes an error of 1 inch in the distance, making it 5 inches instead of 6 inches, then the dose received at 5 inches is actually $\frac{36}{25}$ of that at 6 inches or, since intensity at 6 inches is taken as a unit, it is 1.44 units That is, the dose is increased by 44 per cent due to the error of 1 inch. Now suppose a certain dose at 12 inches is taken as a unit and the operator makes the distance 11 inches instead of 12 inches, the actual dose will also be increased, but in the ratio of $\frac{144}{121}$, or 1.19, as compared to that at 6 inches That is, the dose will be 19 per cent too great. It is thus seen that the same error in distance—1 inch in each case—makes an error in dosage of 44 per cent at 6 inches and only 19 per cent at 12 inches.

QUALITY AND QUANTITY.

It has been the opinion of most roentgenologists, and it is still the opinion of many, that there is a pronounced difference in the biologic and therapeutic value of x-rays of varying degrees of penetrability ("hardness") Some are of the opinion that "soft" rays are especially indicated in the treatment of superficial diseases. Schultz and others endeavor to select a quality that will be absorbed most readily by tissue of a certain specific gravity—hence his advocacy of "very soft" and "over soft" radiation. We have not been able to confirm these findings and opinions. The effect, as evidenced by cutaneous reactions, is always the same if the dose is sufficient, regardless of quality. At least this is true for a spark-gap range from 9 down to 3 inches (140 to 60 kv)

Experiments with x-rays of varying quality in the treatment of symmetrical cutaneous eruptions so far seem to indicate that the therapeutic result is much the same regardless of the penetration (wave length) providing the dose is correct In other words, the therapeutic effect in superficial conditions seems to depend more upon quantity than upon quality

EFFECT OF RADIATIONS ON LESIONS AT A DISTANCE.

It occasionally happens that when treating one or a few lesions of an eruption, other unexposed lesions will undergo involution. Sibley, Fox and others aver that this is a common phenomenon. Occasionally one sees several common warts disappear as the result, apparently, of the irradiation of one lesion. This also happens occasionally in the treatment of other diseases, such as psoriasis, lichen planus, and mycosis fungoides The same phenomenon has been noted when other forms of treatment have been employed. In this connection it must be admitted that all these diseases may undergo spontaneous involution As mentioned in a preceding chapter, acne vulgaris of the face can be cured by irradiating one side of the face, but acne of the back and chest remains unaltered.

RADIUM VERSUS ROENTGEN RAYS

There appears to be little if any difference between the biologic and therapeutic action of *x*-rays and gamma rays of radium They seem to be equally efficacious regardless of the disease providing conditions are as suitable for the one as for the other Gamma rays can be used in locations that are inaccessible to *x*-rays—mouth, nose, vagina and external auditory canal Radium can be placed in needles and radon may be placed in gold seeds, which in turn are inserted into a tumor Small, suitably screened radium applicators can be placed all over and around, and even into a large superficial growth And in many other ways radium can be so manipulated as to obtain a better result than could be had with the *x* rays On the other hand, the *x*-rays are more suitable and more efficient in generalized dermatoses, or for the treatment of diseases that cover large areas For various practical reasons radium is more suitable in one case while *x*-rays will be found more suitable in another Time consumption is an important factor Any practical amount of filtered *x*-rays for cutaneous diseases can be given in a few minutes if so desired The time of exposure for gamma rays will depend upon the amount of radium in the applicator—it is likely to be hours Expense is another item

There is some difference between the results obtained with the beta rays as compared with *x*-rays and gamma rays The elevated type of nevus vasculosus (strawberry mark) often disappears rapidly following applications of beta rays of radium We have never seen such rapid involution in angioma of this type subsequent to roentgenization Beta rays are perhaps more efficacious for leukoplakia They are preferable in the treatment of some of the keratoses In all other diseases the effect of the two agents seems to be very much the same

RADIOLOGIST AND DERMATOLOGIST

Radiology as a broad subject, as an art and science, has been developed by physicists, biologists, radiologists and dermatologists Progress has been so rapid and versatile that it has been almost impossible for any one person to master the entire subject Consequently we now have physicists and biologists who devote most of their time to radiology The work is also very interesting to chemists pathologists cytologists bacteriologists etc In the practical field radiology is divided into roentgenography (diagnosis) deep roentgen therapy, super ficial roentgen therapy and superficial and deep radium therapy Many men are limiting their diagnostic efforts to one portion of the body — head chest abdomen etc Some confine their therapeutic endeavors to the *x*-ray or radium treatment of cancer

Practical cutaneous radiology has been developed by dermatologists, and it is an integral part of dermatology The dermatologist makes the diagnosis, and he knows whether or not a given dermatosis is

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Practical cutaneous radiology has been developed by dermatologists and it is an integral part of dermatology The dermatologist makes the diagnosis, and he knows whether or not a given dermatosis is

amenable to x-rays or radium. He is acquainted with indications, contraindications, complications, sequelæ, etc. He knows how much radiation to apply, when to begin, when to stop, and what results to expect, he knows, also, how to estimate the dose In other words, he is an expert in the use of radium and x-rays for skin diseases. Cutaneous radiology belongs to dermatology, and it is in the hands of dermatology, and there it will remain if dermatologists will keep in touch with the progress that is being made by physicists, biologists, morphologists, chemists and practical radiologists

EQUIPMENT.

We receive many requests for advice from those who are about to equip a dermatologic office or clinic, especially relative to x-ray apparatus. Shockproof apparatus, with thermionic rectification, is the apparatus of the present and future We advise such equipment. Self-rectifying tubes are used by some dermatologists, but the preference is for thermionic rectification with the tube surrounded by circulating cooled oil. Such an outfit permits heavy current and long exposures without overheating the tube.

Non-shockproof units are being used by many and will remain in use for a number of years In some, the rectification is mechanical; in others it is thermionic. So far as therapy is concerned the results are the same with all these types. Mechanical rectification may interfere with near-by radio reception. Thus far the lasting qualities of the shockproof cables have not been all that can be desired. Presumably this and other faults will be corrected in the near future. With a shockproof unit there is no danger of electric shock It is advisable to deal with an established manufacturer who can supply reliable service at short notice.

It is advisable to have a transformer that will generate at least 80 kv.; preferably 190 kv. This will suffice for unfiltered therapy and also for lightly filtered therapy. Naturally, with such apparatus, the time factor is considerable when the filter consists of several millimeters of aluminum. If much filtered work is contemplated, with more than 0.25 or 0.5 mm. aluminum, it is preferable to have apparatus that will supply up to 120 or 130 kv.

Illustrations of apparatus are not in this book. They can be obtained from various manufacturers.

Protection is discussed in Chapter XIV. The exact set-up will depend upon the type of apparatus. Greater protection is required for non-shockproof than for shockproof units. With the former it is advisable for the room to be at least 12 feet square. The ceiling should be high so as to accommodate the overhead high-tension line. Many dermatologists protect themselves by standing behind a lead-lined screen. Such protection has been proved adequate for superficial work, especially with shockproof apparatus, and even with the

older units, but it is inadequate when much filtered therapy is used or when a great many daily treatments are given. Regardless of type of apparatus, the ideal is for the room to be lined with lead or other impervious material and for the controls to be located outside the room. The operator watches the patient and apparatus through a window of thick lead glass.

As stated in previous chapters, intensity must be estimated in roentgens by the ionization method. At least the technic should be checked at frequent intervals by means of an ionization dosimeter, protection should be checked occasionally by the same means, the voltmeter calibration should be checked occasionally and also the wave length or quality by the half-value layer method. It is not necessary for every dermatologist to possess the necessary instruments, knowledge and skill for this purpose. But there should be at least one person in every urban center and in every county or state, in which there are no large cities, who can and will supply this service. There is no good reason why the dermatologist should not do it himself.

Most dermatologists have one radium applicator of the flat type. Some have several applicators of various sizes and shapes. Such applicators are of very limited therapeutic value but they are useful. One small, half strength flat applicator will suffice for the dermatologist provided he has a number of radium needles which can be used for interstitial irradiation or combined into an applicator for external irradiation at a distance of 1 or 2 cm. In fact it is not necessary today to own any radium. The dermatologist can rent radium applicators of any type or he can purchase or rent radon in any amount and in any type of applicator, regardless of where he resides. The principal thing is for the dermatologist to know how, when and why radium and radon should be employed. Protection for the operator in radium therapy is given in detail in the chapter on Radium Technic.

BIBLIOGRAPHY

BÉCLÈRE, A.: The Penetrating Irradiations-Sickness, Am. Jour. Roentgenol., 5: 498, 1918.

COLWELL, H. A., and RUSS, S.: Radium, X Rays and the Living Cell, London, G. Bell & Sons, 1915, p. 58.

EWING, J.: Radium Therapy in Cancer, Jour. Am. Med. Assn., 68: 1238, 1917.

FOX, G. H.: Discussion Regarding Proper Dosage of Roentgen Ray of a Case of Psoriasis of the Palms Presented by Dr. H. Fox, Arch. Dermat. and Syph., 2: 261, 1920.

GUNSETT, A.: Oberflachentherapie mit hohen Dosen hoch gefilterer Rontgenstrahlen speziell bei Kankroiden und bei der Hypertrichose, Strahlentherapie, 5: 219, 1915.

JONES, I. L., and ROTH, P.: The Cause of Constitutional Symptoms Following Deep Roentgenotherapy, *Am. Jour. Roentgenol.*, 5: 32, 1918.

LANGE, S.: The Cause and Prevention of the Constitutional Symptom Following Deep Roentgenotherapy, Am. Jour. Roentgenol., 3: 356, 1916.

LEVY-DORN, M., and BURGHEIM, F.: Zum Einfluss der Rontgenstrahlung auf den Cholesteringehalt im Blute des gesunden und kranken Korpers, Strahlentherapie, 22: 538, 1926.

MARKOVITS, E.: Quoted in Vienna letter, The Prophylaxis and Treatment of Roentgen Nausea, Am. J. Roentgenol., 20: 559, 1928.

MÜHLMANN, E.: Beobachtungen uber Strahlentherapie in Verbindung mit Trauben zuckerinjektionen, Strahlentherapie, 27: 306, 1927.

more chronic forms of the disease At times improvement is rapid, but very often this type is stubborn.

Fig. 125 —Comedo before x-ray treatment

Fig. 126.—Same patient shown in Fig. 125, after 12 weekly (unfiltered, 75 r) applications

Acne Erythematosa —Erythematous acne is seen mostly in females who have gastro-intestinal or menstrual disturbances It consists of

comedos and superficial pustules and more or less erythema of the entire face and at times the back and chest This type is likely to be associated with definite remissions and exacerbations X-rays may not be well tolerated and should be applied cautiously

Acne Indurata —In this type the disease is usually of long standing, the pustules are large and deep seated, frequently indolent and cystic The skin is likely to be sallow and excessively oily Disfiguring scars are present The skin in this type supports *x*-ray treatment well and the results as a rule are excellent

Mode of Action of X-rays in Acne Vulgaris —It was once considered that the effect of radiation in acne vulgaris was due to the inhibition of the overactivity of the sebaceous glands There have, however, been some investigations which suggest that the result of radiation may be due to other factors Niles treated 40 patients with acne vulgaris with routine *x*-ray treatments to one side of the face and placebo treatments to the other side In 26 the untreated side improved as much as the treated side and in 19 of these the untreated side was either entirely cured or almost so These findings were later confirmed by Polano and by Kline and Gahan These results may have been due to the liberation of the protective and defensive substances derived from the destroyed infiltrating lymphocytes This is what Desjardins believes to be the cause of the improvement following radiation of inflammatory conditions as the lymphocytes are especially susceptible to radiation Several investigators have confirmed the fact that *x*-rays do not have a bactericidal effect in acne or other pustular dermatoses

There is also a question as to how much effect is obtained from accidental irradiation of the thyroid gland In a series of patients whom we treated with twelve to sixteen weekly doses of filtered *x*-rays (3 mm Al 125 r) to the thyroid only the face being completely shielded with heavy lead there was distinct improvement in a fairly large percentage and in some a complete cure Sulzberger has used this method with success in several private patients who failed to respond to a course of *x*-ray treatments locally to the face These results may theoretically be explained by the assumption that the amount of iodine secretion (which is normally physiologically increased at puberty) is lessened and that at least in some cases the acne is the result of irritation of the pilosebaceous apparatus by iodine

Advantages of Roentgen Treatment —While the *x*-rays are one of the most efficacious therapeutic agents we have for the management of acne vulgaris yet this method of treatment has been and is being abused The abuse lies in the lack of proper care in the selection of cases, the administration of excessive dosage and the failure to recognize and overcome possible constitutional etiologic factors

It is neither necessary nor advisable to treat every case of acne vulgaris with the *x* rays A new topical remedy known as intradermsulphur has been developed for the treatment of acne vulgaris With

this remedy, plus attention to possible causal or contributory constitutional factors, it is possible to obtain approximately 90 per cent cures in unselected cases with a low percentage of recurrences These results compare favorably with those obtained with *x*-rays. A detailed article on this subject by MacKee, Wachtel, Karp and Herrmann was published in the Journal for Investigative Dermatology in the fall of 1945.

The *x*-rays, if properly applied and combined with other means of combating the disease, offer a treatment that is associated with safety and a reasonably prompt and permanent cure. It is possible to cure a case of acne vulgaris in one treatment by giving at one sitting a quantity sufficient to effect an erythema. Such treatment, however, cannot be too severely criticized and condemned Treatment applied in a manner that is safe will effect a permanent cure with a satisfactory degree of certainty in three or four months, providing that the patient receives proper medical advice and treatment. Roentgen treatment obviates the necessity of using local remedies that are temporarily disfiguring and troublesome and one does not have to depend upon the conscientiousness of the patient. While such treatment necessitates more frequent visits and additional expense, the probability of a permanent cure in a few months, together with the absence of unpleasant local remedies, is ample reason in the minds of many patients for the institution of roentgen therapy.

In 1934, MacKee and Ball published their statistics on 5376 cases of acne vulgaris seen in twenty years of private practice and eight years of clinic practice Of this number, 606 patients received *x*-ray treatment and the final result was determined:

Clinical results.	Private	Clinic
Cured[1]	132—40 6 per cent	108—38 4 per cent
Very much improved	88—27 0 "	76—27 0 "
Much improved	48—14 7 "	39—13 8 "
Total	82 3 "	79 2 "
Improved	41—12 6 per cent	42—14 9 per cent
Slightly improved	8— 2 4 "	7— 2 4 "
Failure	8— 2 4 "	9— 3 2 "
Total	4 8 "	5 6 "

[1] Twenty-four patients in cured group had ten *x*-ray treatments or less

About 41 per cent of the private patients were permanently cured in four months or less, 27 per cent were practically cured, and in about 15 per cent the disease was moderately active at times. This gave a satisfactory result in about 83 per cent of the patients, about 12 per cent received some benefit, while there was complete failure in only 5 per cent. The results in the clinic patients were only slightly less satisfactory: 29.5 per cent of the private patients and 32.7 per cent of the clinic patients relapsed within a year or two Because of the 31 per cent recurrences, it was necessary to reduce the percentage of

the permanently satisfactory results to 52 per cent These figures corresponded almost exactly with our 1927 statistics (see 3rd edition, p 409) There were no untoward results The patients received the routine x ray treatment for acne vulgaris and the cures resulted from weekly treatments over a period of from six weeks to four months

Belisario reported on 102 cases of acne vulgaris treated with $\frac{1}{4}$ erythema dose of radiation unfiltered or filtered with 0 3 mm of aluminum He obtained clinical cure with only eight doses in about 90 per cent In a further 10 per cent, four additional doses were required after a rest period of one month In 10 per cent of the patients who received only eight treatments relapses occurred within twelve months These were improved by four additional treatments of $\frac{1}{4}$ erythema dose

Smith obtained 130 satisfactory results in a series of 169 cases, 23 patients were substantially improved, there were 16 failures

Indications for Roentgen Treatment are to obtain a permanent cure as quickly as possible and to avoid the use of unpleasant local applications In this connection there is another important point In types of acne vulgaris such as acne indurata when the disease may be recalcitrant to other methods of treatment and where the disease consists of deep-seated destructive lesions every additional week of the disease means a few more scars Unless such cases are cured promptly the scarring is exceedingly disfiguring If, therefore a case of acne vulgaris does not improve with reasonable promptness under conventional dermatologic remedies and general medical attention and especially if the lesions are causing scars the institution of roentgen therapy is indicated Even in the absence of scarring it is not proper to allow the disease to continue for many months because in such instances the skin is likely to become coarse and oily Therefore it may be said that if acne vulgaris does not steadily improve under the influence of dermatologic treatment x-rays are indicated

The practitioner might well ask if x ray therapy as used in acne vulgaris constitutes a safe and reasonably certain method of treatment why not apply such treatment in every case? The answer is first, it is possible for the expert dermatologist to cure the disease without the aid of the x rays and, second, because in some hands the x-rays do not constitute a safe method of treatment

Not only must one know how to use the x-rays but one must know when to use them The treatment may be employed to advantage in all the chronic types but it should be delayed in the acute types until the acute symptoms have subsided Furthermore one must know when to discontinue the treatment To cure the disease completely *i e*, to prevent the appearance of even an occasional lesion might in many instances require irradiation to the point of injury to the skin Such treatment is unnecessary and inadvisable

It is the consensus of dermatologists that x-ray therapy should not be used in very young patients, no matter how severe their acne until

all other measures have failed. The reason for this is that recurrences are especially frequent in patients under fifteen years of age. The skin of these patients is also more delicate and prone to reactions. On account of this tendency to recurrence, it is preferable to reserve *x*-ray therapy as a last resort.

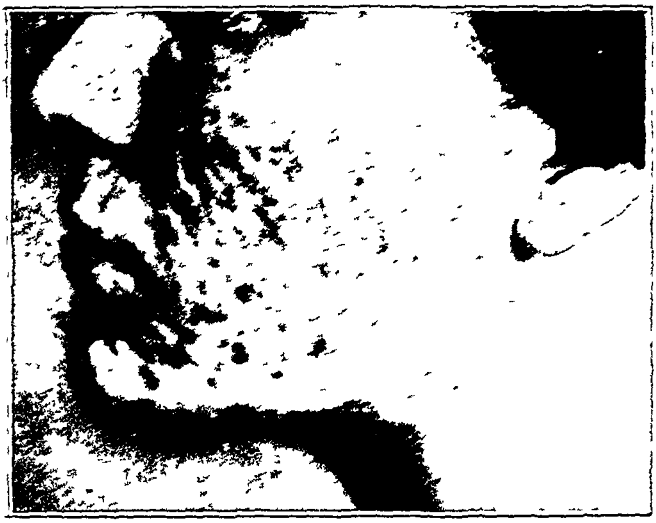

FIG. 127.—Acne indurata before roentgenization.

FIG. 128.—Same patient shown in Fig. 127, after 12 weekly *x*-ray treatments (unfiltered, 75 r). The scars were present long before *x*-ray treatment was begun as can be seen by careful inspection of Fig. 127. There would have been much less scarring if *x*-ray treatment had been used early in the disease.

Menstrual acne, where there is an outbreak of lesions at about the time of the menstrual period and very few lesions between the periods, can be cured by means of *x*-ray treatment it is true, but such cases are

stubborn and if one persists in depending largely or wholly on the x-rays, the skin may be visibly injured

Very mild cases of acne patients who always have a very few comedos and an occasional pustule, are more stubborn, as a rule, than are the more severe examples of the disease X-rays must be employed cautiously in such cases and if the disease is not arrested in three or four months it is advisable to depend upon some other form of treatment

The so-called seborrheic acne is a troublesome type The eruption consists of very few comedos, an occasional pustule, numerous nodules and excessive oiliness Here, too, the tendency is to depend too much on x-ray treatment and persist too long in its use

After acne vulgaris has disappeared there may still be some oily seborrhea, a very few comedos and a coarse skin due to large follicular orifices It is preferable that some treatment other than x rays be applied to improve or cure such conditions

Occasionally, patients acquire the habit of picking every little elevation in the skin The habit becomes almost a mania This condition which is known as neurotic excoriations must be differentiated from acne vulgaris, or, if it is associated with acne, then this element should be recognized and attempts made to correct the habit

This condition is a compulsion neurosis which should be treated by psychotherapy In only a few instances will it respond to radiation and if one persists in this treatment, undesirable sequelæ may occur

Supporting Treatment —It is possible to cure acne vulgaris with the x-rays without any other treatment, but such a procedure is not advisable The object should be to effect a prompt complete and permanent cure with as little x-ray treatment as is possible Possible systemic causal factors should be detected and corrected when they exist

Systemic Treatment —Although for many years it was the custom to prescribe a low-carbohydrate diet, it has been shown by Tauber and Crawford and Swartz and Sutton that, on the contrary a high-carbohydrate diet is of benefit in acne and other pustular dermatoses It is desirable to eliminate fats It is advisable to prohibit the ingestion of iodides and bromides

If there is a tendency toward rosacea or if the acne is of the inflammatory type, the list of prohibited substances should include tea, coffee, alcohol and spices

The bowels should move freely at least once a day If there are indigestion or intestinal troubles, these should be corrected Focal infections should be sought for and corrected

Masturbation and sexual excess must be avoided The menstrual function and genito-urinary tract should receive attention Some patients, especially girls with menstrual disturbances are benefited by sex hormone therapy

Stock and autogenous vaccines and staphylococcus toxoid may be

of service in acne pustulosa and acne indurata. Vitamins and liver, iron or arsenic, either by mouth or injection, may be helpful, especially in patients with associated secondary anemia.

Local Treatment.—It is not advisable to employ irritating and stimulating remedies such as sulphur and mercury ointments, lotio alba, resorcin lotions, etc., in conjunction with *x*-ray treatment. A 10 per cent ointment of zinc oxide may be used with advantage. The affected parts should be washed daily with soap and water. It is advisable to remove the more conspicuous comedos and evacuate the larger pustules at each visit. If efforts in this direction are too strenuous, however, the disease may become worse and unnecessary scarring may be produced.

Erythema doses of ultraviolet rays and excessive exposure to sunlight are not advisable while the patient is receiving *x*-ray treatment.

Relapses.—In spite of every precaution relapses will occur. The percentage varies among different roentgenologists and dermatologists, but it should not be greater than 30 per cent A relapse may denote some important internal factor that has not received proper attention —masturbation, intestinal auto-intoxication, faulty diet, a focus of infection, endocrine imbalance, hormone disturbances, anemia, etc. A relapse may occur within a few months or not for a year or two. As a rule it is mild but occasionally the relapse may be much worse than the original attack.

After the completion of a course of sixteen weekly *x*-ray treatments it is advisable, in case of recurrence or incomplete cure, to depend entirely upon conventional dermatologic therapy.

Technic.—We prefer and advise weekly treatment. The dose is 75 r of unfiltered *x*-rays applied once weekly to the affected areas. The kilovoltage ranges from 80 to 100, depending upon the type of apparatus used The effective wave length is approximately 0.68 Ångstrom unit The approximate millimeters of half-value layers in aluminum is 0 571 Most patients will tolerate such treatment over a period of three or four months without the slightest reaction. If a cure is not effected in four months it is advisable to discontinue *x*-ray treatment The treatments should be stopped as soon as the skin is clear, even if only a few have been given There is no evidence that continuation of the treatment will prevent a relapse.

A few patients will not tolerate this dosage Low tolerance is encountered at times in patients with acne pustula and acne erythematosa and also in young females with a fair, fine-textured, highly-colored skin. In such instances 38 r may be given weekly

It is a good plan to test the patient's tolerance for *x*-rays before beginning the course of treatment For this purpose we employ two contiguous areas of skin, each 1 square inch in size, on the inner surface of the thigh. Exposures of 75 r and 150 r are made. Allowance must be made for the fact that, because of the scattered radiation,

the effect will be about 25 per cent greater when treating large areas like the face as compared to the small areas used for testing tolerance

In all cases the operator should watch carefully for the slightest evidence of erythema and at the least sign of such occurrence the treatment should be interrupted for two or three weeks and then recommenced with smaller doses

As a routine, it is customary to make two exposures to the face at each sitting The anode is placed directly over the outer end of the zygoma of first one side of the face and then the other side With the patient in the recumbent position the face is placed so that the plane of the irradiated surface is at right angles with an imaginary line extending from the anode to the skin This will allow the radiation to spread over one side of the face and the side of the neck The oblique rays from the two exposures will overlap on the forehead, nose and chin While this method does not provide equal dosage over the entire face it answers practical requirements

In some patients with lesions entirely or chiefly on the center of the face it is advisable to apply 75 r to the front of the face alone

When treating the face the eyes, eyebrows scalp, ears and chest must be protected with lead foil or other suitable material It is advisable to protect the lips

If the chest is affected it is preferable to treat it separately If the eruption is limited to the chest one exposure with the anode over the center of the sternum will suffice, care being taken to shield the face and neck If the eruption is on the anterior surfaces of the shoulders and arms two exposures are necessary the anode being placed first on one side and then on the other side The tube may be placed over a horizontal line drawn through the nipples and each treatment must be at least 12 inches apart A distance of 14 inches between the perpendicular anode-skin lines for the two treatments is preferable It is important not to have this distance less than 12 inches The arms are placed alongside the thorax in such manner that their anterior surfaces will be on a level with the anterior surface of the chest The oblique rays are allowed to overlap at the center of the chest The face and neck should be protected Occasionally it is necessary to give separate exposures to the external surfaces of the arms

Two exposures will usually suffice to cover the upper back, the back of the neck and the posterior surfaces of the shoulders and arms The anode is placed 1 or 2 inches mesially to the posterior axillary folds, the arms are held against the sides of the body, the scalp is covered with lead foil The oblique rays from the two exposures are allowed to spread over the back and the nucha Here too the exposures must be at least 12 inches apart If the entire back is involved reasonably equal exposure can be obtained by focusing the anode over two points on the upper back 12 inches apart and over a third point on the lower back 12 inches from a point half way between those on the upper back

Possible Dangers.—With caution, judgment, and modern technic there is little, if any, danger of a first-degree reaction. Without an erythema it is exceedingly doubtful if it is possible for telangiectasia to develop. In the *x*-ray treatment of well over 5000 cases of acne vulgaris in office and clinic, we have not had a single example of radiodermatitis or telangiectasis or atrophy.

If the treatment is continued for too long a time (over four months) there may develop slight wrinkling and dryness. The dryness usually disappears in a few months due to regeneration of the appendages but wrinkling is more likely to be permanent. In this connection it should be interjected that acne may cause wrinkling independent of treatment, and that atrophy from any cause may not lead to wrinkling

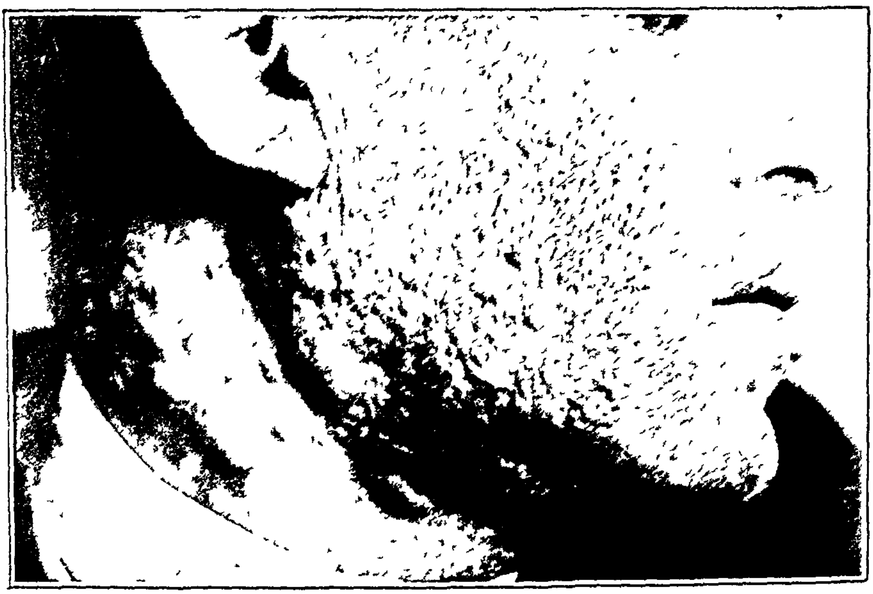

FIG. 129. Acne vulgaris showing active lesions and very severe scarring due to the disease. This patient has not received *x*-ray treatment. Most of this scarring could have been prevented by *x*-ray treatment.

until the patient is older, thinner, or both. While atrophy to the point of visible wrinkling will occur in any person if the treatment is continued for a sufficiently long time, or if the doses are of sufficient size, yet idiosyncratic tendencies in this respect must be admitted. For this reason the operator should study the skin carefully at each visit. Skin that has a low tolerance can often be detected during a course of treatment by its irritability. It will be found to react more vigorously to friction, to heat, to light, to emotional excitement, etc., than it did before roentgen therapy was instituted. In such instances the dose should be made smaller and a longer interval allowed between treatments.

It has been claimed that the *x*-ray treatment of acne vulgaris causes a growth of hair at times. It is a fact that a growth of down is occa-

sionally seen subsequent to the x-ray treatment of acne But it is seen just as frequently in cases of acne that have not been treated with the x-rays No one has noticed a growth of hair following the x-ray treatment of psoriasis, eczema mycosis fungoides, leukemia, epithelioma and various other diseases The question of the hair-growing powers of the x-rays is discussed at some length in Chapters XXI and XXXIII Suffice it to say here that hypertrichosis following acne vulgaris is probably due to the disease itself There is no evidence to prove that irradiation of acne vulgaris causes or favors a growth of hair

It has been claimed by some patients and even by a few physicians that more scarring follows acne vulgaris when treated with x-rays than when treated in other ways The opinion has been expressed that x ray treatment interferes with the normal production of new connective tissue Several suits have been based on this belief It is the consensus that the best way to avoid scarring in severe cases of the disease is to check the disease as soon as possible and x rays may be used for this purpose Acne no matter how treated, is likely to produce scars One patient will scar more than another, even with the same type of lesion, and with the same treatment The scars are often overlooked while the face is covered with indurated pustules They do not become conspicuous as a rule until the disease is cured Scars often improve and even disappear in a few years

In a series of 40 patients treated by Niles with x rays to one side of the face and a placebo treatment to the other the scars were equal on both sides in 32 cases, more pronounced on the untreated side in 5 and greater on the treated side in 3 Kline and Gahan appropriately duplicated Nile s results

Pigmentation or tanning is not a serious result of irradiation but when occurring on the face it is disfiguring and sometimes it is so annoying cosmetically that patients refuse to continue roentgen treatment Excessive pigmentation occurs in a small percentage of cases (usually in dark-skinned individuals) and may consist of freckles or a diffuse tanning Rarely it is prominent and results from a few mild applications There is no way to avoid this idiosyncratic tendency It is not a contraindication to x ray treatment but the patient may prefer another form of therapy At times the pigmentation will disappear in a few weeks subsequent to cessation of x ray treatment In some instances however, several months and even a year or two is required for complete disappearance of the discoloration (For the treatment of this condition see chapter dealing with radiodermatitis and complications and sequelæ of x-ray treatment)

Filtration —Filtration in superficial diseases is discussed elsewhere in this book Suffice it to say here that we have tried both filtered and unfiltered rays in acne vulgaris and insofar as can be determined the therapeutic result is approximately the same We do not use a filter in treating acne vulgaris but we do not advise against its use for this purpose

ROSACEA.

Roentgenization is of no value in pure rosacea, *i. e.*, telangiectasis and diffuse erythema. When combined with acne vulgaris, or with acneiform lesions and oily seborrhea, as is usually the case, the *x*-rays are of value. The acneiform lesions often disappear and the sebaceous glands may become less active. With the disappearance of the pustules there is less congestion of the affected parts.

Rosacea is due to constitutional disturbances, often of the gastro-intestinal canal, therefore it is not advisable to depend upon the *x*-rays alone for a cure. As a routine the system of interdictions given for acne should be followed. It is important that tea, coffee, alcohol and spices be prohibited. The bowels should be carefully regulated With proper attention to diet, hygiene, and the correction of underlying causes, very severe types of rosacea can often be cured by fractional treatments in three or four months. In spite of the erythema and inflammation, the skin affected with rosacea usually tolerates the *x*-rays very well We prefer and advise conventional dermatologic therapy, resorting to *x*-rays only after such treatment has failed.

While the patient is under *x*-ray treatment it is not advisable to employ the strong ointments and lotions that are usually prescribed for rosacea Multiple scarification and electrolysis, for the purpose of destroying dilated capillaries, is permissible and advantageous Soothing lotions and ointments (zinc oxide ointment, calamine lotion) are beneficial and are gratefully received by the patient

Rosacea is limited, as a rule, to the so-called flush centers of the face—nose, chin, mesial portions of the cheeks and the lower and middle parts of the forehead. The technic as described under acne vulgaris may be used in the treatment of rosacea—two exposures, one for each side of the face, the oblique rays being allowed to overlap at the center of the face, or one exposure may be made to the center of the face with the anode directly over the nose. If the condition is limited to the nose the rest of the face should be shielded and an exposure made to each side of the nose In this instance, in order to avoid too much overlapping of the radiation on the bridge of the nose, the plane of the lateral surface of the nose should be at right angles to a line extending from the skin to the anode.

Hypertrophic rosacea is a sort of borderline between rosacea and rhinophyma It may be benefited by roentgenization especially if there are many pustules For a complete cure, however, it is necessary to resort to other forms of local treatment and to correct underlying causative conditions

RHINOPHYMA.

The *x*-rays are of little if any value in rhinophyma The result will depend upon local conditions Acneiform lesions will disappear and the sebaceous glands may become less active. The cure of rhin-

ophyma, however, requires other forms of local treatment including surgical measures

ACNE VARIOLIFORMIS

It is difficult to estimate the true value of the x-rays in acne varioliformis The disease usually yields readily to topical remedies, although recurrence is the rule Furthermore, while running a long course, there are remissions, periods of latency and exacerbations We treated 25 cases of this disease with the x-rays In every instance the eruption subsided in about a month with treatment In most of these cases there was a recurrence Our impression is that x rays are of little value in the disease so far as a permanent cure is concerned

Acne varioliformis affects mostly the forehead and scalp, occasionally the nose The technic of application will depend upon the distribution of the eruption If limited to the nose, this organ is irradiated as explained under the heading of rosacea If the forehead is involved the hairy parts and the face are shielded and weekly 75 r doses applied with the anode placed over the center of the forehead If the lesions are situated in the eyebrows and on the anterior scalp these parts are left unshielded and doses of 38 r administered once weekly for a month If the eruption is scattered over the scalp the entire head is irradiated by the Kienbock-Adamson method (Chapter XXVII), the dose being 38 r once weekly for four treatments It is unsafe to administer more than 150 r in a month, otherwise a defluvium of scalp hair may result This amount will usually suffice for a temporary cure, if not, there should be an interval of rest of one month before further irradiation If the eruption involves the face and scalp the former may be left unshielded while applying the Kienbock-Adamson method

SYCOSIS VULGARIS

Until recently irradiation was the therapeutic method of election for this disease The topical use of penicillin tyrothricin and other remedies has been so spectacular that x ray treatment is likely to be seldom used in the future

Bowen was one of the first if not the first, physician in this country to report the successful use of the x-rays in sycosis vulgaris He reported the cure of 11 cases in 1903

Marin considers that from the standpoint of therapeusis there are three types of sycosis (1) Those which clear up after 8 to 12 weekly unfiltered treatments, (2) those which require temporary complete epilation, and (3) those in which the first two types of treatment have failed and require permanent epilation Those patients in whom the first type of treatment has failed should after six weeks' rest, be given the second type He reported on 17 cases of sycosis cured by x rays Thirteen received small weekly doses and 4 temporary epilation None required permanent epilation

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FIG. 130 —Sycosis vulgaris before *x*-ray treatment

FIG 131 —Same patient shown in Fig 130, after *x*-ray treatment In this case it was not necessary to cause temporary alopecia The eruption was bilateral and symmetrical

The literature contains many articles dealing with this subject The following exposition of roentgen therapy in this disease is based on personal experience and a knowledge of the literature

The results obtained with x-rays in sycosis vulgaris range from brilliant to poor As a rule, the best results are obtained in cases of short duration but we have seen long standing cases of this condition (ten to fifteen years duration) permanently cured as a result of a few weekly exposures Judging from our experience some cases can be cured by weekly treatment in a month or so without epilation especially if vaccine therapy and other methods of treatment are used Many cases will require a defluvium Occasional cases demand permanent alopecia and at times even permanent alopecia will not effect a cure

Recurrence in this disease is common and the relapse may or may not yield to further roentgenization

Technic —The technic of application is the Kienbock method which is described in detail in Chapter XXVII This technic is applicable to cases where the disease is limited to the bearded region Rarely the disease affects the eyelashes eyebrows anterior scalp hairline axillæ and pubes In such instances these parts are treated separately

Eyelashes and Eyebrows —The lids are closed and covered with a thick coating of a 50 per cent ointment of zinc oxide or bismuth subnitrate A still better method is to fasten properly patterned pieces of lead foil or lead rubber to the lids with zinc plaster The remainder of the face is shielded and the radiation is applied first to one exposed region and then to the other

Anterior Hairline —The face, scalp ears and neck are shielded Two exposures are made with the anode centered over the temporal regions The oblique rays are allowed to overlap at the center of the anterior hairline

Axillæ —The patient lies on his back and places his forearm under the head All parts excepting the axillæ are shielded An exposure is made first to one side and then to the other side with the anode centered over the center of the axilla In the position given the axilla is a little concave but with the anode at a distance of 8 inches dosage will be sufficiently uniform over the affected area

Pubic Region —The unaffected parts are shielded One exposure with the anode placed over the center of the pubic region will usually suffice to cover the affected area

Dosage —Inasmuch as weekly treatment without defluvium will suffice for a cure in some cases it seems advisable to try such treatment first Seventy-five roentgens once weekly for from four to eight treatments will suffice for a trial If the desired result is not obtained it may be advisable to depilate To produce a defluvium of the bearded region without the advent of at least a mild first-degree reaction is a difficult matter It is almost impossible with one treatment It usually requires at least 300 r to effect defluvium and this

quantity is very likely to evoke an erythema of the skin of the face. As a matter of fact, it usually requires 375 r, or even 450 r administered at one sitting, to cause the hair of the male beard to fall out. It is unwise to administer doses of this size to the face for this purpose because of the danger of an *x*-ray erythema. The reason for this attitude is that even a mild *x*-ray erythema may be followed in time by telangiectasia.

There are two ways in which the latitude of safety can be increased. Filtration is one method. With filtered radiation one has a little more latitude between the amount necessary for epilation and the amount that will effect an erythema.

The other method consists of applying 75 r every three days for four, five or six doses, or 113 r every five days for three or four doses. The hair may fall out one week after the last treatment. If not, it becomes necessary to continue the treatment, with the same doses and intervals, until a defluvium results. The same method may, of course, be used with filtered radiation. In some instances it is possible to depilate the beard by this method without the advent of even a mild first-degree reaction.

The main point is that in obstinate cases of sycosis vulgaris one is working with a quantity of radiation that is very close to that required for a mild first-degree reaction, therefore the patient must be kept under close observation for signs of cutaneous irritability which often occur when absorption is close to the saturation point. This irritability is manifested by a pronounced temporary erythema following friction, exposure to heat, light, wind, exertion, or when the head is lower than the body, or it may be coincident with emotional excitement.

If, after fractional treatment has failed to effect a cure, it is decided to push the treatment to the point of epilation, it is wise to allow a rest interval of three weeks before changing the technic.

For medicolegal reasons it is advisable to acquaint the patient with the difficulties and possibilities of the treatment and to have one or more physicians in consultation. If he has tried other forms of treatment, skilfully and conscientiously administered, without success, he will usually accept the slight-risk with the understanding, of course, that there is no alternative and that the operator will employ a modern technic, requisite skill and judgment.

In dealing with unusually refractory or relapsing examples of the disease when the treatment as outlined above has failed, the advisability of effecting a permanent alopecia can be considered in consultation.

Permanent Alopecia.—The first step is to depilate the hair with the technic already outlined. If no further radiation is administered the hair will begin to grow again in a month or two. To prevent this regeneration it is necessary to apply 150 r or 225 r once monthly for from four to eight months, and in some instances even longer.

In effecting a permanent alopecia there is little, if any, danger of

FIG 132 —Sycosis vulgaris before x ray treatment (Courtesy of Dr Howard Fox)

FIG 133 —Same as Fig 132 after x ray treatment It was necessary to effect permanent loss of hair to cure this patient (Courtesy of Dr Howard Fox)

telangiectasia, providing there is no erythema at the time of the defluvium, but there is danger of more or less wrinkling and dryness of the skin. Wrinkling will occur in some cases and not in others. There is no way to avoid this sequela with certainty and the patient should clearly understand this fact.

A man afflicted with a bad case of this most disfiguring and annoying disease, assuming that the eruption has resisted skilful and intelligent dermatologic treatment, will willingly sacrifice his beard and he will be glad indeed to risk the chance of atrophy and even of telangiectasia to be permanently rid of his disgusting affliction.

It is very uncommon to see sycosis vulgaris persist after permanent alopecia has been effected, but the disease has been known to exist in a modified form after the beard has been permanently lost. The explanation is that lanugo hairs are still present and may, in certain individuals, become the seat of the disease.

It should be borne in mind that severe sycosis vulgaris may cause more or less permanent alopecia, atrophy and scarring. The *x*-rays must not be blamed for sequelæ caused by the disease itself.

FURUNCULUS AND CARBUNCULUS.

The *x*-rays are of service in the treatment of recurrent boils in any given area as, for instance, the back of the neck and the axillæ. One suberythema dose will often prevent the development of new lesions. It may be necessary, in order to effect a cure, to depilate the parts. If this is attempted in one treatment erythema is likely to result. For reasons given elsewhere in this chapter it is desirable to avoid an erythema Weekly doses of 75 r unfiltered, without the advent of erythema, will often suffice for a cure. If, however, it is necessary to cause a defluvium, it is preferable to do so by means of the technic and dosage explained in detail under the heading of sycosis vulgaris.

The older literature contains many reports of excellent results, in the case of a carbuncle or boil, with a single large dose of filtered *x*-rays (3 mm. Al, 250 to 500 r). We have obtained good results with 250 r. But in recent years *x*-rays and radium have been used only occasionally because better results are now obtained with the sulfonamides, penicillin and bacteriophage In a recent article O'Brien favors the use of *x*-rays with or without other methods of treatment.

PARONYCHIA.

We have had a few good results and many failures with the *x*-rays in the treatment of chronic pyogenic paronychia. Ormsby has found such treatment of service. Pfahler reports the cure of a very long-standing case with twenty-five mild treatments over a period of three months Higgins treated 6 cases of paronchyia with eight doses of 150 r each and cured only 2 Rohrbach and Webster report good results but give no statistics.

Lack of experience does not permit the constructing of an exact technic It is well to shield the fingers to within ¼ inch of the nail We employ unfiltered radiation, 75 r weekly, for from four to eight treatments Larger doses might be more effective but they may lead to sequelæ It is permissible to use penicillin ointment in conjunction with *x*-ray treatment Our results with filtered radiation were no better than with unfiltered rays

GRANULOMA PYOGENICUM

Clark cured one case of granuloma pyogenicum with one treatment with radium Remer cured 2 cases of granuloma pyogenicum with two suberythema doses of beta rays of radium (personal communication) Hodges obtains good results with 700 to 900 r of unfiltered *x*-rays in simple and telangiectatic granuloma Marin believes that *x*-rays and radium constitute the methods of choice for the treatment of granuloma pyogenicum He reports a number of cases in which about 1200 r of unfiltered *x*-rays caused the lesions to disappear in six weeks without leaving a trace

MISCELLANEOUS

One case of dermatitis vegetans was treated with unfiltered weekly doses without effect

Two cases of what was thought to be chronic streptococcic lymphangitis were cured by *x*-ray treatment In one instance the disease involved the nose being secondary to a disturbance in the nasal passage The eruption consisted of thickening of the skin redness and occasional pustules The duration was three years during which time there were remissions and exacerbations The disease disappeared after sixteen treatments at weekly intervals The patient also received vaccine treatment

The second patient presented a palm sized area of red thickened skin on the left cheek Sharp exacerbations associated with the development of numerous pustules occurred frequently The duration of the condition was six years Three unfiltered doses of *x*-rays (225 r) were administered at monthly intervals There was no improvement until after the third treatment when the eruption disappeared The patient has remained well over a period of six years

Chronic indolent ulcers supposedly of staphylococcic or streptococcic origin are at times benefited by a few weekly applications of *x* rays or radium

A number of patients with abscesses of the face chest and back associated with acne vulgaris (acne cachecticorum acne conglobata) were apparently greatly benefited by weekly *x* ray treatment combined with other measures directed at the general health

Two cases of ulerythema sycosiforme (lupoid sycosis) have been cured with three applications of *x* rays (unfiltered, 150 r monthly)

Fig. 134 —Ulerythema sycosiforme (lupoid sycosis) before x-ray treatment.

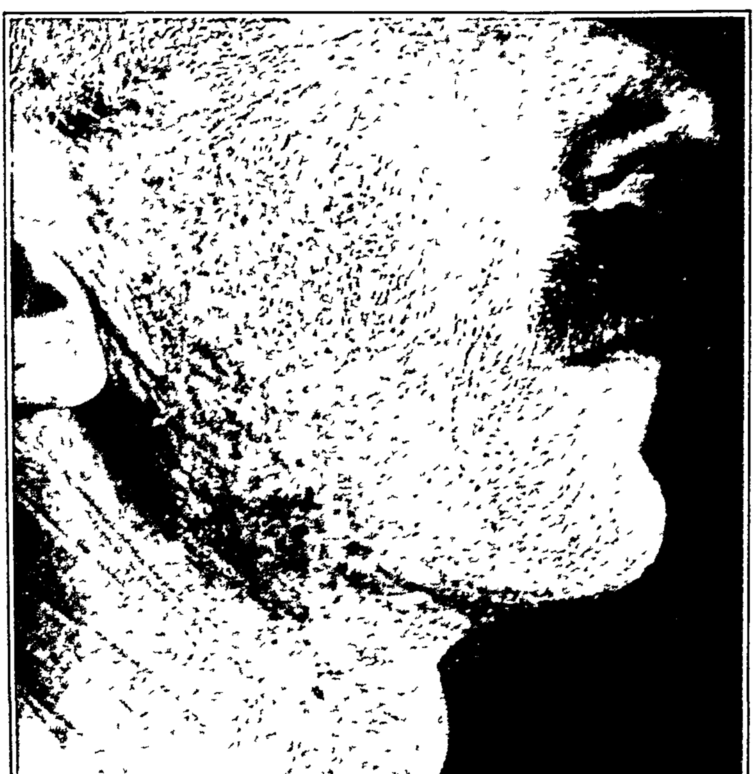

Fig. 135 —Same as Fig 134 after x-ray treatment

Allen cured a case of this disease with x-ray treatment The disease recurred in six months but again disappeared under roentgenization Our cases were treated many years ago The patients have not been seen since Three cases of a somewhat similar condition—*folliculitis decalvans*—were cured by a single epilating dose Angle cured a case of this disease with weekly x ray treatments over a period of six months Of course the x-rays had no effect on the permanent alopecia and atrophy caused by the disease itself This disease and lupoid sycosis cause atrophy and permanent alopecia sequelae that should not be blamed on x-ray treatment

The very stubborn staphylogenic impetigo has been reported cured with x rays But today modern conventional dermatologic therapy is so efficacious for most of the pyodermas that x-ray treatment is seldom indicated or employed

ERYSIPELAS

The sulfonamides and penicillin have been so successful in the management of erysipelas that it is doubtful that x-rays will ever again be used for this disease unless, for some reason, the patient can not tolerate these remedies

Results with x rays have been fairly good The complete literature and detailed technic will be found in the third edition of this book, page 433

BIBLIOGRAPHY

BELISARIO J C Treatment of Acne Vulgaris With Special Reference to X rays Med Jour Australia 2 656 1935

BELOT J Radiotherapy in Skin Diseases New York Rebman Company 1905 p 441

BOWEN J T Methods of Teaching Dermatology Trans Am Dermat Assn 1903 p 11

CLARK A S Radium in Dermatology Am Jour Med Sci 169 355 1925

COYLE R R Odds and Ends of X ray Work Including Some Cases of Carbuncle Med Electrother and Radiol 7 139 1906

CRAWFORD G M and SWARTZ J H Acne and Carbohydrates Preliminary Report Arch Dermat and Syph 33 1035 1936

DESJARDINS A U Radiotherapy for Inflammatory Conditions Jour Am Med Assn 96 401 1931

HODGES F M Roentgen Therapy of Certain Infections Am Jour Roentgenol and Rad Ther 35 145 1936

KLINE P R and GAHAN E Unilateral Roentgen Irradiation in the Treatment of Acne Vulgaris Arch Dermat and Syph 46 207 1942

MACKEE G M and BALL F I Acne Vulgaris and Roentgen Rays A Statistical Report Radiology 23 261 1934

MACKEE G M WACHTEL J KARP F L and HERRMANN F The Evaluation of Intraderm Sulphur for Acne Vulgaris Jour Invest Dermat 6 309 1945

MARIN A Sycosis et rayons X Presse méd 40 1673 1932 Sycosis and X rays Canad Med Assn Jour 28 621 1933 Du traitement radiothérapique du granulome pyogénique Presse méd 40 1022 1932

NILES H D Roentgen Rays in the Treatment of Acne Evidence That They Do Not Produce Scarring Arch Dermat and Syph 27 89 1933

O BRIEN F W Treatment of Severe Carbuncles by X Ray New England Jour Med 220 917 1939

PFAHLER G E A Case of Chronic Pyogenic Onychitis Cured by the X ray Jour Cutan Dis 23 356 1905

POLANO, M K. Beitrage zur Kritik der dermatologischen Therapie Acne Vulgaris, und Rontgenbestrahlung, *Dermat Wchnschr*, **97**, 1070, 1933

ROHRBACH, R Die Rontgenbehandlung der chronischen Paronychie, Strahlentherapie, **35**, 136, 1930

SMITH, L. M Results of Treatment of Acne Vulgaris by *X*-Rays and Other Physical Methods, Texas State Jour Med, **38**, 512, 1942

SULZBERGER, M J Personal Communication

TAUBER, E B Hyperglycemia in Diseases of the Skin, Arch Dermat and Syph, **27**, 198, 1933

WEBSTER, J H D Treatment of Inflammatory Conditions by Radiations, Brit Med Jour, **2**, 665, 1932

CHAPTER XXVII

DISEASES DUE TO FUNGI *

Of the cutaneous diseases due to pathogenic fungi the following respond in varying degrees to treatment with x-rays or radium

1 Tinea Capitis	6 Moniliasis
2 Favus	7 Actinomycosis
3 Tinea Barbae	8 Blastomycosis
4 Onychomycosis	9 Sporotrichosis
5 Tinea of the Glabrous Skin	10 Granuloma Coccidioides

TINEA CAPITIS

(Ringworm of the Scalp)

Historical Sketch —Freund in 1897 was the first to suggest the use of x rays in the treatment of this disease Cures were soon reported by Schiff and Freund Kienbock Torok, and Schein and many others The technic used at that time consisted in applying inaccurately estimated fractional doses two or three times weekly until a defluvium resulted The results at first encouraging were negatived by the large percentage of cases of permanent alopecia due to excessive dosage

In 1904 Sabouraud and Noire devised a method of depilating the entire scalp at one sitting They employed their own radiometer a description of which is in the second edition The method consisted of dividing the scalp into ten or twelve areas and exposing each area to an epilating dose as estimated by means of a pastille As each area was treated the remaining portions of the scalp had to be carefully shielded a specially constructed metal cone of proper size shape and length being used for the purpose This metal cone was called a localizer It served to confine the radiation to a definite area and to keep the head in constant relation to the source of radiation It also contained a receptacle at half distance for the pastille In the course of a year or two they depilated many hundreds of cases with an exceedingly low percentage of untoward results

The work of Sabouraud and Noire was watched with no little interest by dermatologists and roentgenologists of other countries Ringworm of the scalp was disappearing from France as a result of the new method of treatment Naturally the method was given a trial in other countries especially in England But the results were not favorable,

* In the last edition this chapter was revised by Dr George M Lewis Some of the material added by Dr Lewis has been retained in this edition

the percentage of cases of permanent alopecia was too high. In France they employed static machines, in England coils were used. At first very little was known relative to pastille characteristics. Nevertheless, in spite of many difficulties and discouraging results, the English roentgenologists persisted and it was not long before their efforts were crowned with success.

Kienböck, in 1907, devised a very ingenious method of dividing the scalp into five areas. No protection was necessary except for the face, ears and neck. Each area was given a pastille dose. The oblique radiation from one area reinforced similar radiation from other areas, thus providing equalization of quantity over the entire convex scalp.

Two years later Adamson published an excellent article in which he modified the Kienböck method and explained in a very practical manner the details of the technic. With the Sabouraud-Noiré technic it required four hours to apply the treatment to the entire scalp. Adamson's technic reduced the time to one and a half hours.

It was still necessary to place the pastille at half distance and to use some method of fixing the head. Fixation of the irradiated part was of the utmost importance when the pastille was placed at half distance. The popular method of fixation was to have soft wooden pegs attached to the tube-stand. These pegs could be adjusted to keep the head in proper relation to the *x*-ray tube. Soft wood was utilized because the pegs were in the field of radiation and if they were composed of hard wood too much radiation would be lost by absorption. Hampson, in 1911, overcame these difficulties by estimating the dose with the pastille on the skin instead of at half distance.

With the advent of the Coolidge tube, the interrupterless transformer and electrical methods of measurement, roentgen technic in the treatment of tinea capitis became standardized.

Epstein, in 1933, pointed out the great overdosage which occurs with the multi-field irradiation of curved surfaces. A report by Molesworth and Riddle in 1935, based on calculations and photographic comparisons, dealt with the effect of the angle of incidence on the dose of *x*-rays absorbed by the skin. They found that when the Adamson-Kienböck five-point technic was used for irradiation of the scalp, a greater dose of *x*-rays was received in the intermediary areas between the centers of irradiation than was received at the five central points (Fig. 136). They believed that the angle of incidence of a beam of *x*-rays had little or no practical influence upon the dose actually absorbed in tissue lying immediately below the irradiated surface. Since the areas where overlap occurred received a much greater dose than that received at the centers of irradiation, Molesworth and Riddle concluded that the margin between the smallest dose which will cause epilation and the largest dose which will just fall short of preventing regrowth must be greater than was heretofore considered Shanks noted that in cases where the hair failed to regrow after roentgen epilation, it was the centers of irradiation which escaped and in

some instances the hair in these areas did not even fall out Roxburgh and Kinnear considered that the opinions of Molesworth and Riddle were based on faulty interpretation of formulae and that the theoretical aspect was not proved by practical experience Kinnear stated that in nine years of experience he had always obtained an even epilation following the administration of x-rays He pointed out that the five centers must be accurately located the tube centered

Fig 136—This photograph illustrates the greater dose of x rays received in the intermediary areas between the centers of irradiation than was received at the five focal points When this boy was observed several months later there was complete and uniform growth of hair all over the scalp

exactly, and each exposure given at an exact right angle to the others Other requisite factors included a constant source of radiation accurate timing and complete stillness of the patient

Epstein measured by ionization methods the amount of radiation delivered to various points of the scalp during a roentgen epilation He agreed with the statements of Molesworth and Riddle On most areas of the scalp, owing to overlapping, there was an increase in dose

up to 50 to 80 per cent, compared to the dose applied to each separate field Single points received nearly 500 r In the case of a boy, aged four years, a single field received a dose of 540 r by mistake. No further radiation was administered. A perfect epilation in the area irradiated took place without any visible reaction, and regrowth of hair was first observed after nine weeks Subsequently there was a complete regrowth of hair Schreus and Proppe agreed with the findings of Molesworth and Riddle, and Epstein. They described a four-point irradiation technic which they state will give a uniform dose distribution over the entire scalp with no increase of radiation in the intermediary parts of the scalp

The authors, with the collaboration of Mutscheller, studied this whole question concerning epilation of the scalp using four, five and six points. Up to the time of this writing about 200 cases have been treated with a four-point technic devised by the authors. After elaborate experimentation and clinical observations of a large series of cases treated by the four-point method, we agree that the five-point Kienbock-Adamson technic permits overirradiation between the focal points. However, this overirradiation is not dangerous and will not cause permanent depilation provided all phases of the technic are properly carried out. Attention to details is necessary regardless of the technic employed. The only real advantage to the four-point method is the saving of time This advantage is overcome by the fact that the five-point method is more mechanical, easier executed, a more uniform epilation is obtained more often and, finally, it has stood the test of time. The authors favor the five-point method of scalp epilation A complete description of our four-point technic is not given here because we advocate, as we always have, the five-point Kienbock-Adamson method of scalp epilation A detailed description of our four-point method with illustrations has been published and the reference to it may be found in the bibliography at the end of the chapter.

It is agreed by everyone that the greater the focal skin distance, the greater the overlapping and also the greater the intensity of radiation. It is interesting that theoretical considerations and experimentation at this point indicate a degree of danger not entirely considered by workers during the past thirty years In the hands of responsible and experienced operators, the five-point technic for epilation is still being used with uniform success The danger from overlapping would appear to be potential but from a practical standpoint may be safely ignored If a skin target distance of 8 inches (20 cm) is used, the degree of overlapping is not sufficiently great to cause concern.

Depilation of the entire scalp is accomplished today in this country by the Kienbock-Adamson technic with the exception that the dose is estimated by a combination of electrical and ionization measurements (combined technic) With modern methods a trained technician rarely requires more than one-half hour for treatment of the five areas unless

the patient is very unruly. It is possible to treat the five areas in less than half of this time if necessary or advisable.

Value of X-ray Treatment.—Ringworm of the scalp varies in respect to severity of symptoms, type of organism and number of cases. In localities where the disease is common and intractable it is a positive menace to society. In large cities there are thousands of children afflicted with the resistant types of this disease. Such children are a menace to their fellows and, as they often are not allowed to attend school, the disease must be considered as one cause of illiteracy.

Roentgen treatment effects a cure in one sitting. In the majority of instances the child can return to school in about two months. If the treatment is administered by one who is properly trained in the work there is no danger of any kind to the child. Unfortunately there are very few free clinics and not many private laboratories in this country where these patients can receive modern treatment with *x*-rays. It would be a splendid thing if the health boards of large cities became interested to the extent of equipping a clinic with modern apparatus and furnishing one or more trained technicians to work under the supervision of a dermatologist who has had the necessary roentgenologic training. In the absence of such clinic, the health authorities might refer patients to a clinic where the work is properly done.

It is interesting to note the results, from an economic and sociologic standpoint, that were obtained in France at the very beginning of the work. The fungi responsible for tinea capitis in France were and are predominantly either Microsporon audouini or one of the endothrix Trichophytons. These types are resistant to treatment by topical measures. At the Paris ringworm school prior to 1903, the average time required for a cure was two years. About 300 cases were hospitalized and about 110 were annually discharged cured. After the institution of *x*-ray therapy the cure required three months, and in the first year 327 cures were effected.

Types of Tinea Capitis.—The diagnosis of tinea capitis may be frequently made on clinical grounds alone. Localized patches of alopecia, the presence of short broken off hairs and various degrees of inflammation on the scalp of a child are highly suggestive of ringworm. In every case, however, the clinical diagnosis should be verified by examination of the scalp under filtered ultraviolet rays, by examination of the stubby hairs in a potash preparation, or by the cultural determination of the causal fungus. All three procedures should be carried out. The knowledge gained from the cultural study is of practical value since the type of therapy to be pursued should depend on the species of organism causing the infection. If favus be included in the discussion one may divide these fungus infections of the scalp into two groups according to the causal organisms:

I. Fungi which are usually transferable to animals.
  (*a*) Microsporons—M. lanosum, M. fulvum, etc.
  (*b*) Trichophytons—usually ectothrix—Tr. gypseum.

II. Fungi which are usually not transferable to animals:
(a) Microsporons—M. audouini, etc.
(b) Trichophytons—usually endothrix—Tr. violaceum, etc.
(c) Achorions—A. schœnleinii (favus).

The clinical features frequently lead us to suspect one of the above types, *but clinical impressions are sometimes erroneous. Each patient* should receive the benefit of a cultural diagnosis. Ringworm of the scalp is caused either by M. lanosum or M. audouini. The other organisms are causative in a small number of the total cases. In the present epidemic of scalp ringworm, the predominating organism is the M. audouini. In general one may postulate that fungi which are also pathogenic to animals produce a greater inflammatory response on the scalps of children than do fungi not transferable to animals. Sometimes in patients with ringworm due to fungi also pathogenic to animals, the inflammatory reaction is mild and is evidenced solely by perifollicular erythema and scaling. At other times there are follicular pustules and, in severe infections, boggy infiltrations develop. This latter condition is known as kerion. It is usually in infections from fungi in this group that secondary toxic rashes develop (microsporid, trichophytid).

In the second group, the visible inflammation is usually slight. In infections caused by M. Audouini, the term "gray-patch" is frequently used as descriptive, although considerable erythema and follicular pustulation may sometimes be noted. In infections caused by fungi of the endothrix Trichophyton group, localized follicular pustules may develop and small crusts limited to the region of the infected hairs are common. In other instances, the hair breaks off at the level of the scalp, but no visible inflammatory reaction is noted. Favus will be discussed in a later paragraph of this chapter. However, the clinical features may be briefly mentioned here. The usual picture is the presence of scutulæ or follicular crusts which produce pressure atrophy leading to permanent alopecia. The infected hairs are usually lighter in color than normal, but may not be "broken-off." Another variety of favus of the scalp may resemble seborrheic eczema Very little alopecia is produced, and the scaling present may be mistaken for dandruff.

Indications for Roentgen Epilation.—When an infection of the scalp is caused by fungi which are also pathogenic to animals, epilation of the scalp hair by means of the *x*-rays is rarely, if ever, required. If the inflammation is severe enough to produce large pustules and kerions, it is customary to apply mild wet compresses; spontaneous cure usually follows without the necessity for intensive treatment. In infections of less severity, fungicidal applications with frequent washing of the scalp with soap and water is usually sufficient to effect a cure. It seems that when infections respond within two to twelve weeks to topical applications alone, one is not justified, except for special reasons, in advising roentgen epilation.

In infections of the scalp which are caused by fungi not usually transferable to animals, epilation with x-rays is the method of choice. Microsporon audouini, Trichophyton violaceum, and Achorion schœnleinii (favus) are the organisms of this group most commonly isolated in New York. Some physicians prefer to produce depilation of the scalp hair by means of the thallium salts. Lewis and Hopper were unsuccessful in effecting cure of such infections by topical remedies of many different kinds, estrogenic substances, attempted substitution of another fungus, short wave ultraviolet rays and treatment by vaccines. If the extent of the fungus infection is slight, manual depilation may be sufficient to effect a cure in some cases.

X-rays vs Thallium Salts as the Method of Choice for Epilation. — Depilation of scalp hair from the ingestion of the thallium salts is a routine procedure in some clinics. The results in the hands of some observers have been excellent and the method is preferred by them. Thallium acetate is also of use when roentgen therapy is not available. Due caution, however, must be shown since poisonous by-effects are common. We do not advise the use of thallium acetate because it is dangerous. As many as 25 per cent of the patients to whom the drug is administered may develop reactions of varying intensities. Some of the reactions may be so severe as to cause death. The drug is very seldom used in the United States for the treatment of tinea capitis.

Filtered Ultraviolet Rays. —The use of filtered ultraviolet rays (Wood's light) as a diagnostic measure in ringworm of the scalp was first advocated by Margarot and Deveze. Many observers have since confirmed their findings of the regular occurrence of fluorescence when infected hairs are observed under the rays. Anyone undertaking to treat patients with ringworm of the scalp should be equipped with a suitable apparatus to observe the scalps of all patients not only for diagnostic purposes but in order to follow the course of the disease and determine when cure has occurred.

Apparatus. —Formerly any ultraviolet ray source—usually a Kromayer light—was used. The ultraviolet rays passed through a special glass filter containing about 9 per cent nickel oxide. Now special lamps are made for the purpose by leading manufacturers. The Westinghouse, Hanovia and Stroblite Companies supply suitable apparatus at low cost. Special bulbs may even be used. These, however, are not very efficient.

Appearance of Hairs Infected With Fungi. —In Microsporon infections the infected hairs may be observed as bright green stumps. In infections due to Trichophyton endothrix the affected hairs are dull and bluish. In favus the hairs are greenish but less luminous than in infections with Microsporon. In Trichophyton ectothrix no fluorescence is noted. Many skin diseases have a characteristic appearance when observed with filtered ultraviolet rays. Costello and Luttenberger have recently published an article dealing with this whole subject.

Preparation of Patient for Treatment.—The preparation of a patient for roentgen treatment of tinea capitis is of considerable importance. The most important point of all is to ascertain what treatment has been recently applied to the scalp. If irritating ointments or lotions have been used (iodine, croton oil, mercury, sulphur, chrysarobin, tar or salicylic acid), it is preferable to allow a period of two weeks to

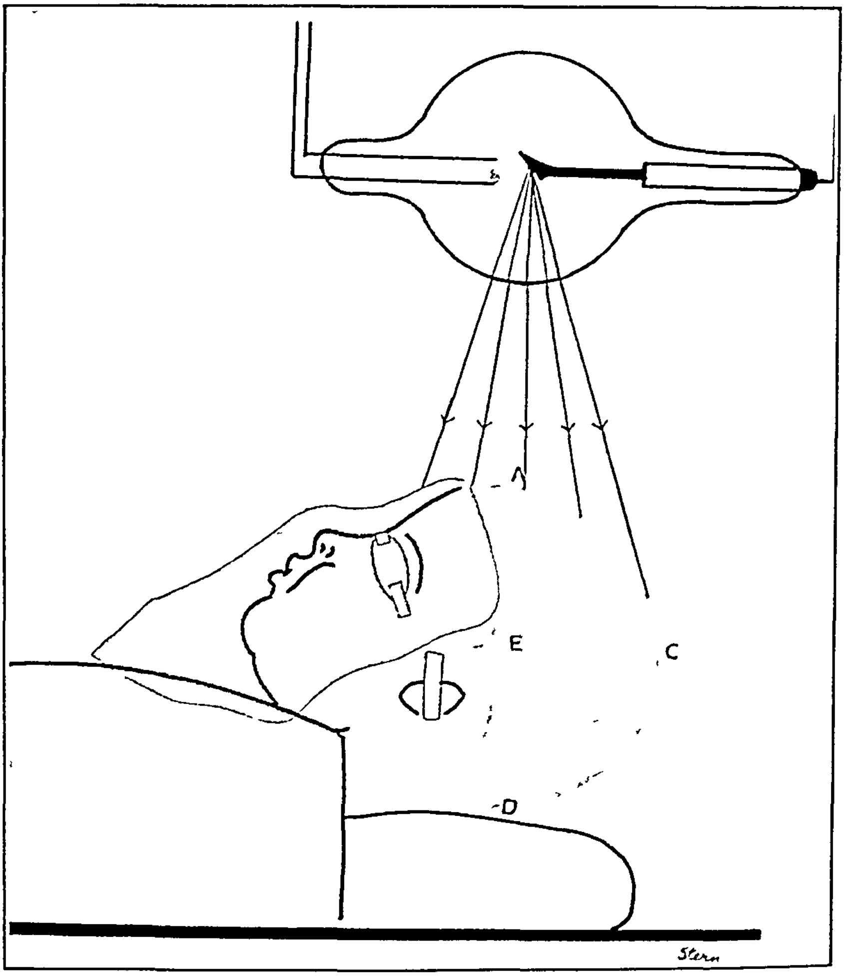

Fig 137 —Position for epilating point A The patient lies in a supine position with his head supported by sandbags The entire face is protected by a lead shield Note that the shield touches the anterior hairline The central portion of the beam of x-rays strikes point A perpendicularly.

elapse between the last application and the roentgen treatment. If the scalp is inflamed as a result of such applications, a period of two weeks should elapse after the disappearance of the inflammation before the x-rays are administered.

The hair should be cut close to the scalp Removal of the hair not only facilitates making the necessary marks and lines (to be described later) on the scalp, but a bald head is much easier to handle than

one containing a wealth of long hair The head should be washed with soap and water prior to the treatment

Finally with nervous or unruly children, one or more rehearsals may be necessary before the child acquires sufficient confidence to allow the head to be placed in position and to keep it in position during the treatment As a rule it is remarkable how well these little patients behave but occasionally a child is encountered that tries the patience

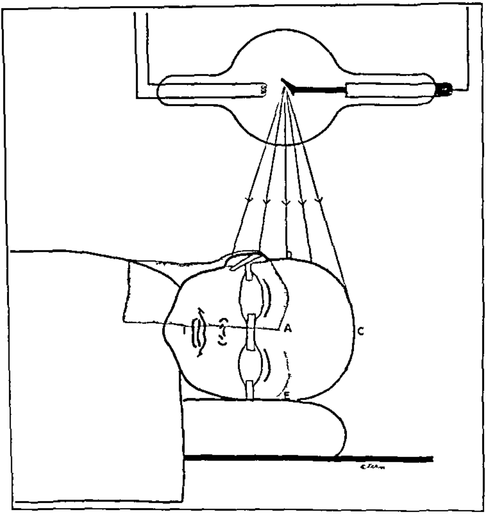

FIG 138 —Position for epilating point D The patient lies in a supine position with his head turned to one side and supported by sandbags A protective lead shield covers the entire face

of the physician and technician to the limit of endurance Occasionally it is necessary to administer an opiate before the treatment

Age of Patients —As a rule it is impossible or at least very difficult to depilate the entire head of a child under two or three years of age for the simple reason that the patient will not remain quiet It is well not to epilate the scalp of an infant because there is theoretical danger

that this dose might delay closure of the fontanelles and union of the suture lines. In children under two years of age methods of treatment aimed at control and prevention of the spread of the disease should be instituted. Cure, if possible, should be attained with topical remedies

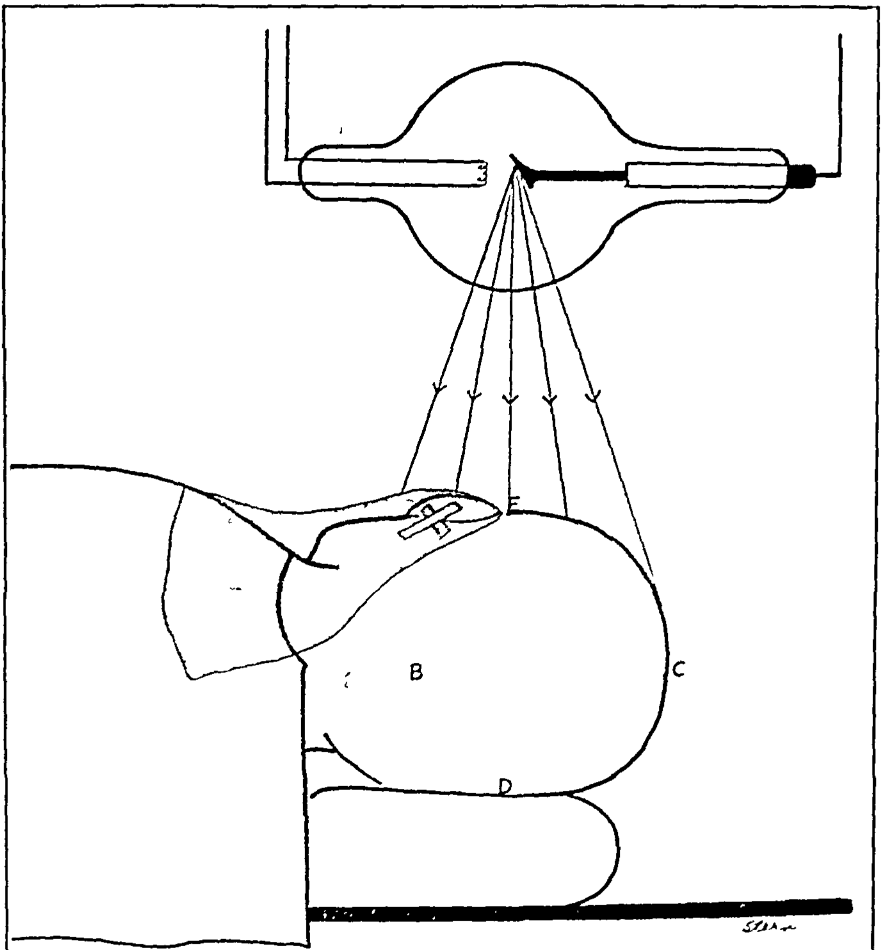

FIG 139 —Position for epilating point E The patient lies in a supine position with his head turned to one side and supported by sandbags. The entire face and back of neck are protected with lead shield

Technic.—The method of marking the scalp and the angles of incidence herewith described were first advocated by Adamson Proceed as follows: The circumference of most scalps measures 19, 20 or 21 inches The directions which follow apply to a 20-inch scalp. For a scalp measuring 19 inches the points are 4.75 inches from each other and one measuring 21 inches, the points are 5.25 inches from each other. A mark is made (with a skin pencil) 2 inches (5 cm.) inside of the hairline above the forehead in the median line (Fig. 137) This may be designated as point A. A steel tape measure is then placed

with zero on point A and stretched along the median line over the vertex to the neck At 10 inches (25 cm) another mark is made—point B (Fig 140) This will usually be about 2 inches (5 cm) inside of the hairline on the back of the neck but will vary somewhat in accordance with the size of the head Points A and B should be adjusted so that they are about the same distances inside of the anterior and posterior hairlines As a matter of fact A and B, in some

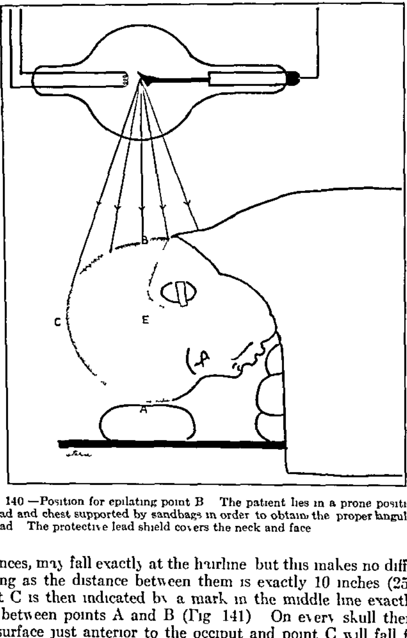

Fig 140 —Position for epilating point B The patient lies in a prone position with the head and chest supported by sandbags in order to obtain the proper angulation of the head The protective lead shield covers the neck and face

instances, may fall exactly at the hairline but this makes no difference so long as the distance between them is exactly 10 inches (25 cm) Point C is then indicated by a mark in the middle line exactly half way between points A and B (Fig 141) On every skull there is a flat surface just anterior to the occiput and point C will fall from 1 to $1\frac{1}{2}$ inches (2 5 to 3 75 cm) in front of the center of this area One may insist upon point C being exactly at this location and adjust A

and B so that they will be just 5 inches (12.5 cm.) anterior and posterior to C. Point D is then located just above and in front of the right external auditory meatus (Fig. 138). The exact position of this spot is found by measuring 5 inches (12.5 cm.) from A, B and C. Point E represents the same location on the left side. It is essential that each point be exactly 5 inches (12.5 cm.) from the next nearest point.

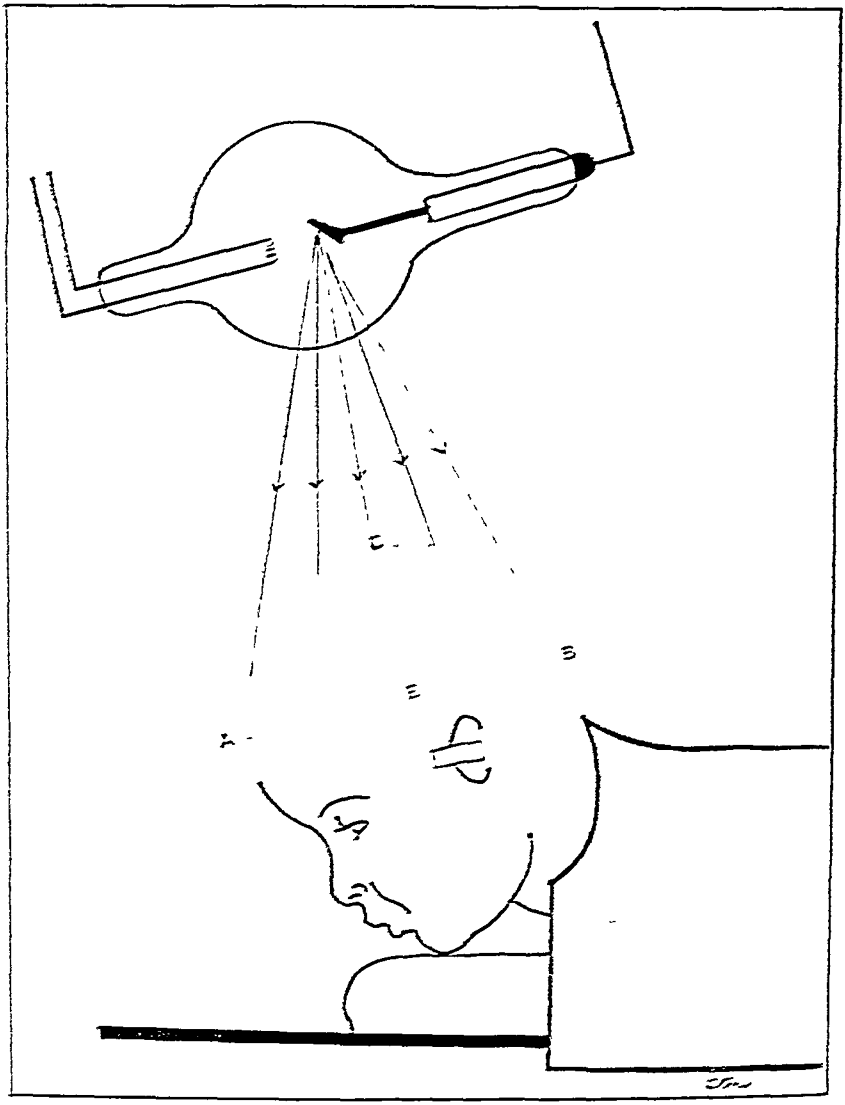

Fig. 141.—Position for epilating point C. The patient lies in a prone position with the chin resting on a sandbag. The x-ray tube is tilted so that the central rays of the x-ray beam strike point C perpendicularly. A protective lead shield covers the neck and back.

The next step is to draw lines between the various points (Fig. 154). This will divide the scalp into four triangular areas. The reason for this will be made clear later.

Next, each point—A, B, C, D and E—receives an epilating dose of x rays in the following manner

For point A the child lies on his back on a table The entire face below the hairline is protected by lead foil or other suitable material The tube is placed with the anode exactly over and exactly 8 inches (20 cm) from point A (Fig 137) It will be seen that the vertical rays will strike point A, while half of the oblique rays will fall upon the anterior and lateral portions of the scalp

While the patient lies on his back points D and E are irradiated The patient twists his head to one side and the ear face, chest and shoulder are protected with lead foil The ear is held down with adhesive plaster in order to irradiate the hair in front and in back of the ear Usually the right side is irradiated first This is done to establish routine and habit so that if the operator is interrupted during treatment there is little likelihood of forgetting which side was first irradiated The perpendicular rays strike points D and E and the oblique rays fan out over the anterior posterior and central portions of the scalp The right antero lateral portion of the scalp receives oblique rays from three points namely A C and D The left antero-lateral portion of the scalp receives oblique rays from points A C and E The same applies to the postero-lateral portions of the scalp receiving radiations from points B C and D and B C and E It can thus be seen that the lateral portions of the scalp receive x-rays from three points The amount of radiation which falls on the lateral portions of the scalp is greater than that falling on each of the focal points

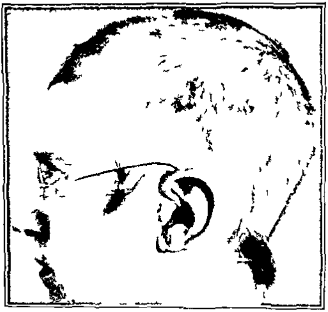

FIG 142 —Unequal regrowth of hair occasionally seen after treatment The areas where hair is growing slowly were previously occupied by the disease The end result was perfect

The amount has been estimated as about 50 per cent greater than the epilating dose. Thus it is that hair falls sooner and grows more slowly in the lateral portions of the scalp. However, this amount of over-irradiation is not dangerous and will not lead to permanent alopecia or to radiodermatitis if the technic is carefully carried out. This method of scalp epilation has certainly stood the test of time.

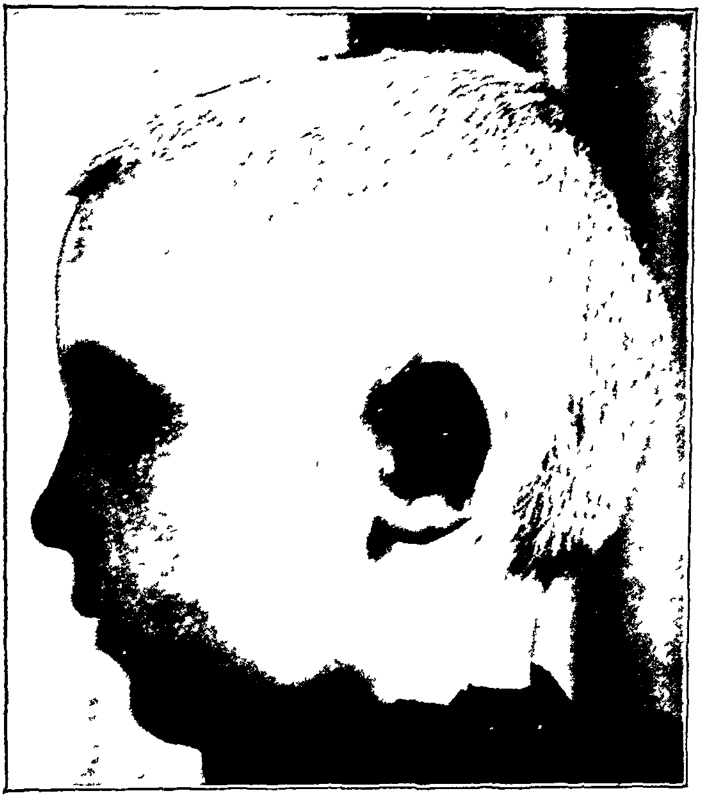

FIG. 143 —Shows the loss of hair resulting from a single exposure to Point D without exposures being made to other parts of the head

The patient then lies on his stomach with the forehead resting on a low firm pillow and the chest raised from the table by the use of sandbags. Point B is now irradiated, the dermatologist remembering to protect with lead foil the back, shoulders and ears. The perpendicular rays fall on point B and the oblique rays fan out over the entire occipital area and lateral surfaces of the scalp.

Point C is the most difficult to irradiate because the patient has to maintain an awkward position for several minutes. The patient lies on his stomach and the chin is raised from the table by the use of sandbags. It is desirable to raise the head sufficiently so that a plane through point C is parallel to the table. The ears, face and back are protected while point C is irradiated. The oblique rays fall towards the anterior, posterior and lateral surfaces of the scalp.

It is of the utmost importance that each treatment be at right angles

to every other treatment For instance, an imaginary line drawn from the anode to point A will be at right angles to lines extending from the anode to points C D, and E Figs 137, 138, 139, 140 and 141 will explain these angles better than words and, also, they will demonstrate that the lines drawn on the scalp between the five points aid one in quickly determining the correct angle

FIG 144 —This photograph shows how loose hair is removed with adhesive tape 18 to 21 days after an epilating dose of x rays is applied according to the Kienbock Adamson technic in a case of tinea capitis

A study of these illustrations will show also how the vertical rays strike the five points while the oblique rays from one treatment overlap and reinforce similar rays from other treatments For instance, if a full epilating dose is administered to point E and to no other portion of the scalp the hair will fall out over only a very small area (Fig 144)

The Dose —There does not appear to be very much difference in the susceptibility of the scalps of children between the ages of two and twelve insofar as epilation is concerned Three hundred r (1 skin unit,

unfiltered) measured in air with the Seitz-Glasser type Victoreen r meter which has been specially calibrated for use with low voltages is the epilating dose This will nearly always produce a complete defluvium This is a safe dose but it must not be exceeded except in cases where the tolerance is known to be greater. Two hundred and twenty-five r (¾ skin unit) has been known to produce defluvium in a female blonde, twenty-two years of age, who had psoriasis At the other extreme it required 375 r (1¼ skin units) to depilate the head of a female brunette afflicted with favus To depilate the scalp of an adult 350 to 400 r are required

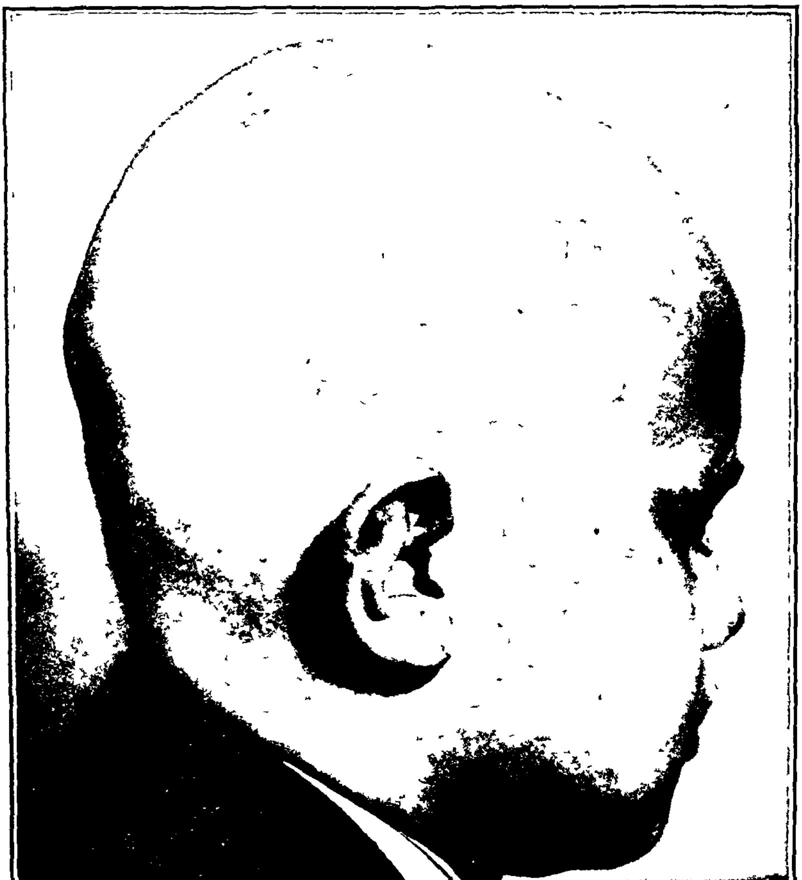

FIG 145 —Shows complete and uniform epilation 21 days after x-rays were applied according to the 5-point Kienbock-Adamson method Three hundred r were applied to each of the five focal points

The epilating dose is to be administered to each of the five points in succession in one session If for any reason the five areas cannot be treated at one sitting it is permissible to expose one area daily increasing by 10 per cent the dose applied to each point If the intervals are greater than this the hair may fail to fall out. The beginner should not attempt the x-ray treatment of this disease until his apparatus

has been calibrated by a physicist and his technics have been standardized and repeatedly checked, and he has had experience with the x ray treatment of various cutaneous conditions He must be certain of his epilating or erythema dose which are the same and correspond with the skin unit

We and our associates have employed the combined method of dose estimation (Chapter XVII) in this work for over twenty years The heads of over 6000 children have been depilated without a single case of permanent alopecia Hazen reported 225 patients treated in this manner In one instance there was permanent baldness and in another patient the subsequent growth of hair was sparse Hazen was able to locate a technical error thus supporting the accuracy of the method if properly conducted The bad result in one patient was due to the stopping of a watch and in the other it was due to too much motion of the head H Fox and Anderson treated 98 children with tinea capitis by the combined x-ray method There were no bad results The hair failed to fall out in 5 cases We, also, have had a number of cases in which the hair did not fall, and the treatment had to be repeated The failures were due to overconservatism In a recent publication by C Guy Lane and Crawford this statement appears The average amount of radiation required to produce 100 per cent epilation was a little over 300 r (300 6) as measured by the Victoreen meter ' This confirms our published reports and those of Holthusen who added further that epilation is not dependent upon quality within certain limits

Filtered X-rays —It is doubtful if filtration offers any advantage In fact it would seem to be contraindicated because of severe systemic reactions and possible injury to the brain Buschke, Kleinschmidt and Gutmann report severe systemic reactions and Buschke and Klemm not only these, but radiodermatitis, permanent alopecia and failure to depilate in a large proportion of their cases Light filtration medium voltage and a dose of no more than 350 r to each point should be safe and effectual if all other points of the technic are carefully carried out

Margin of Safety —The margin of safety is considerable Permanent alopecia has never resulted from a dose of 300 r (1 skin unit) Occasionally the hair will fall after an application of 225 r In some instances epilation will not be effected by a dose of 300 r It probably requires 500 r or more to effect permanent alopecia Very small areas will of course tolerate larger doses than will full-sized areas

Fixation of Head —It has been found by experience that most children will hold their heads quietly during the exposure if they are properly handled Some become nervous frightened and unmanageable if an attempt is made to fix the head by use of sandbags, weights, and various mechanical devices A little time and patience usually overcome any fears that a child might develop One cause of restlessness on the part of the child is sparking from the protective lead foil

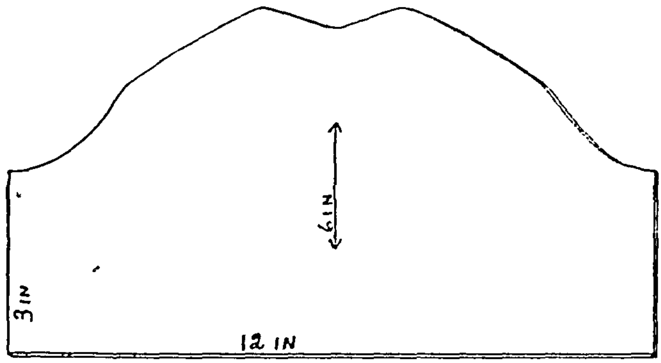

FIG 146 —Lead-rubber shield for face.

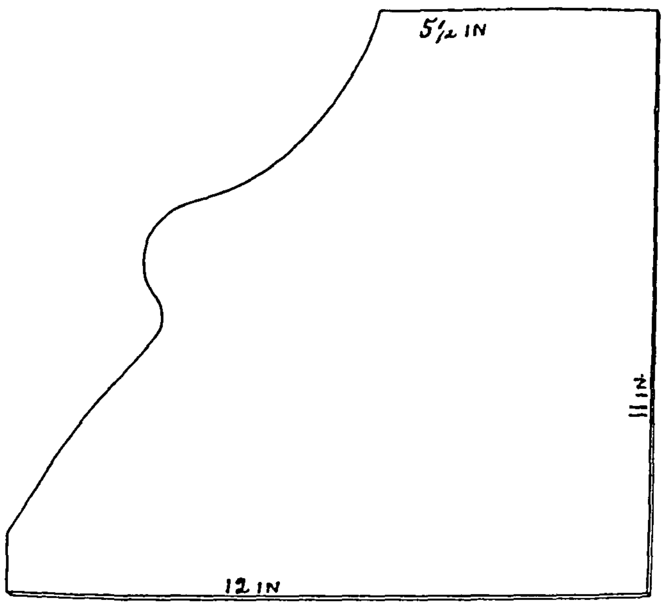

FIG 147 —Lead rubber shield for side of face, ear, side of neck, and shoulder

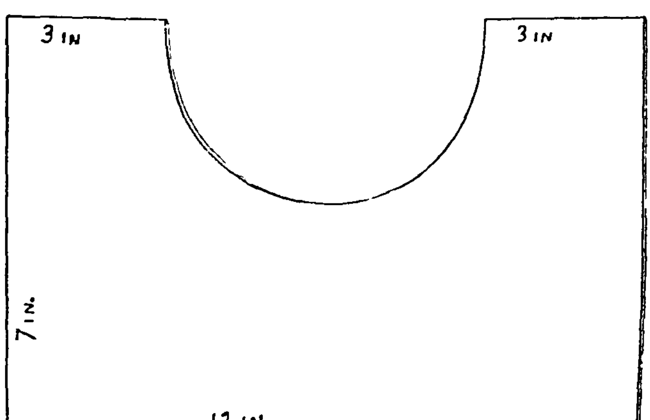

FIG 148 —Lead-rubber shield for back of neck

This can be prevented by using lead-rubber instead of lead foil. A sheet of this flexible material can be cut into three patterns—one for the forehead and anterior face, one for the side of the face, neck and ear, and one for the back of the neck and shoulders (Figs. 146, 147 and 148). The same patterns will answer for every child and they will last for years. Excessive restlessness can be lessened by the administration of an opiate but it is seldom necessary.

Time, Distance, Voltage and Milliamperage.—These factors may be anything the operator desires within reasonable limits. If the work must be done rapidly, amperage or voltage may be increased. Experience has shown that for the majority of cases a working time constant of two or three minutes is satisfactory. It is neither too slow nor too rapid. Greater rapidity is likely to be associated with less accuracy; longer exposures try the patience of the child.

Our work has been done with between 60 and 100 kv. Theoretically a lower voltage because of less penetration might be preferable. Higher voltage might produce too much penetration. It is preferable, for routine work, to increase the milliamperage instead of changing distance or voltage when very short exposures are necessary.

All factors must, of course, remain constant throughout the exposure. The only important difficulties will be associated with time and distance. The time should be kept with a stopwatch. The operator must, so to speak, keep one eye on his milliammeter and voltmeter and the other on the patient's head. If the head moves perceptibly upward, downward or sidewise, the exposure must be at once interrupted. It is such interruptions that are likely to cause confusion in timing the exposure and this is the reason for the stopwatch.

Subsequent Events.—Some children exhibit a slight elevation of temperature, loss of appetite, restlessness and other symptoms of mild indisposition the day of, or the day following the treatment. These symptoms are not common and may be ascribed to the nerve strain or may be a mild variety of radiation sickness. In no instance have convulsions or other alarming symptoms been noted. It is possible that this systemic reaction might be avoided if lower voltage is used.

A week or two after the treatment there may be a very slight erythema of the scalp which subsides in two or three days leaving pigmentation. Pigmentation may develop without antecedent erythema. This is rarely observed. A week or ten days subsequent to the treatment all the ringworm areas are likely to become inflamed and painful. This is especially marked in instances when the lesions are numerous and active and particularly so in the infrequent occasions when the *x*-rays are used in the treatment of the suppurative type of the disease. The child is likely, under these circumstances, to show toxic symptoms including a more or less generalized erythematous, papular or squamous eruption. These reactions are seen in tinea capitis caused by the *M. lanosum*. None of these symptoms need occasion alarm.

A true first-degree radiodermatitis *i. e.*, an erythema developing from five to ten days subsequent to the treatment and enduring for from one to three weeks, may or may not be followed by permanent alopecia The outcome is simply uncertain. In the majority of such instances the hair will regrow, although its reappearance will be delayed and the new growth is likely to be sparse and not of good quality. If the reaction is associated with edema or erosion (second-degree reaction) the hair in all probability will not regrow. The cause of a first- or second-degree radiodermatitis is practically always overdosage.

Ordinarily the defluvium begins about the eighteenth day and is complete by the twenty-first day. It may occur a few days sooner or a few days later A complete defluvium, while desirable, is not always necessary for a cure We have seen cures follow very incomplete depilation At the time of defluvium there may be a faint erythema which disappears in a few days.

FIG 149 —Disseminated ringworm before treatment

Fig 145 shows a head that was depilated by the Kienbock-Adamson five-exposure method It will be noted that there is no hair remaining. The patient made a complete recovery Figs 149 and 150 represent a patient with disseminated ringworm before and after irradiation Fig 150 shows the tanning so often seen subsequent to the treatment Patches of apparent depigmentation corresponding in size to the original areas of tinea may be noted as a temporary sequel This is usually observed in Negro children.

The hair begins to regrow in from one to three months subsequent to the defluvium If there is no evidence of regeneration in six months permanent alopecia may result The regrowth of hair is usually vigorous but at times it is sluggish These variations depend, apparently, upon the size of the dose Very rarely the new hair is of different quality from the original growth If the original growth was curly the new hair might be straight and *vice versa* It may be a little coarser or a little finer in texture Also, the color may be a little lighter or slightly darker These variations may be idiosyncratic Sometimes the new growth of hair will be less rapid in the ringworm areas than on portions of the scalp where there was no disease

Fig 150 —Same as Fig 149 after treatment by the Kienbock Adamson five-exposure method

Time saving Devices —The lead-rubber shields mentioned in a previous paragraph are a great comfort They do not cause sparking and they do not irritate and annoy the patient They can be adjusted in a few seconds Being flexible and heavy they remain in place They were first used by A Howard Pirie of Montreal

A marker or stencil was devised by MacKee and Andrews which also saves time A description of this marker and its use follows

Heads because of age sex race etc differ somewhat in both size and shape This makes no material difference in the results obtained

with the Kienbock-Adamson method of preparing the scalp for roentgen-ray treatment (see below). It does, however, make it difficult to construct an instrument or marker that will instantly and accurately indicate the Kienbock-Adamson points and lines on any head.

FIG 151 —Tinea capitis and tinea of the glabrous skin prior to x-ray therapy

The circumference of the head of the average patient with tinea capitis is 20 inches (50 cm), providing the circumference is obtained from points in the sagittal plane, 1½ inches (3 75 cm) inside of the anterior and posterior hairlines and from points 1 inch (2 5 cm) above each pinna Measured in this manner, the heads of some children show a circumference of 21 inches (52 5 cm), while in others the circumference is only 19 inches (47 5 cm.) The circumference of adult heads, free of hair, is usually about 22 inches (55 cm).

The instrument or marker has been used for some time, and it has given admirable service in ways that will be mentioned later It can be made by the operator out of an ordinary flexible steel tape-measure The marker is simply a duplication, in metal or other

material of the Kienbock-Adamson points and lines The base is a circular band to which are attached two crosspieces The ends of the crosspieces are riveted to the circular band at the anterior, posterior and lateral points The intersection of the two crosspieces is also riveted A glance at the photograph of the marker will show that the crosspieces are set at right angles to each other and at right angles to the circular band

For children, the marker is made in three sizes The one that is used by far the most has a circumference of 20 inches (50 cm) and the Kienbock-Adamson points are 5 inches (12 5 cm) apart For smaller heads the circumference is 19 inches (47 5 cm) and the points are $4\frac{3}{4}$ inches (11 875 cm) apart For the larger heads the marker has a circumference of 21 inches (52 5 cm) and the points are $5\frac{1}{4}$ inches (13 125 cm) apart

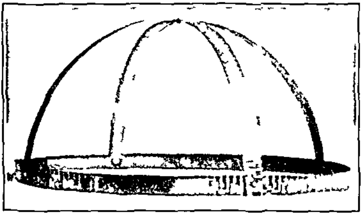

Fig 152 —Homemade tinea marker Made of steel tape measure Circumference 20 inches

After the scalp hair has been closely clipped it requires about ten minutes to mark out a scalp by the tape method The time consumed will depend upon the skill of the operator the shape and size of the head and above all the behavior of the patient

It requires not more than sixty or ninety seconds to map out the scalp with the tinea-marker The child instead of being apprehensive is rather amused and interested The instrument is used as follows The patient s family should be instructed to have the patient s hair cut very close to the scalp Hair clippers should be used The marker is then placed on the scalp with the anterior and posterior points in the middle line and at equal distances inside the anterior and posterior hairlines A line is then drawn on the scalp along the inferior border of the circumferential band Lines are also drawn along the crosspieces Dots are made at the intersecting points The marking can be done with a skin pencil with ink or with a dull pointed indelible pencil that has been moistened with water In the

case of a very dark skin, white ink is advantageous Iodine or other irritating chemicals should not be employed for this purpose.

Possible Dangers.—The possible specific dangers associated with the x-ray treatment of tinea capitis consist of permanent alopecia and injury to the brain.

Fig 153 —Tinea-marker (homemade variety) placed in proper position on scalp

Fig 154 —After the scalp has been mapped out with the tinea-marker and an indelible pencil, and the marker removed

MacLeod disposed of the second item as long ago as 1909 We and our associates have treated over 6000 patients in the past thirty years In France and England many thousand cases have been so treated Yet there is not a single record in the literature of injury to the brain—either immediate or remote This is true for children of any age, even infants, and with any quality of radiation, with the understanding of course, that the dose is limited to that required for epilation

Fig 155 —Atrophy telangiectasia and permanent alopecia due to excessive x ray dosage

Thirty years ago permanent alopecia following irradiation for tinea capitis occurred rather frequently Then in a period of about five years this unfortunate result occurred in the proportion of about 2 or 3 in 1000 Most of the experienced operators have had no such cases in the past twenty years We had 1 case of permanent alopecia in 1912, the result being due to a technical error made at a time when technic was comparatively very unreliable Since 1912 not a single case of permanent baldness has occurred in our laboratories in spite of the fact that the technical work has been done by a number of physicians, technicians and students, always, of course, under proper supervision As far as can be ascertained by experience and a knowledge of the literature, there is no danger of permanent alopecia without an antecedent radiodermatitis of at least the first degree There is no danger of such radiodermatitis on the scalp unless the dose has exceeded 300 r or unless there has been an error of judgment such as using irritating chemicals repeating the x-ray treatment too soon in case of relapse etc There is always the question of idiosyncrasy but, fortunately, this unpleasant possibility is uncommon

Williams studied the hair after the administration of intensive and fractional doses of x-rays. He found no nutritional changes in the hair after a single epilating dose. When repeated small doses had been applied to the scalp nutritive alteration of the hair was quite marked. In this connection Adamson noted ringed hairs (alternate light and dark areas due to irregular air content) among the depilated hairs following a single epilating dose. It can be said with certainty, after over thirty years' experience with the *x*-ray treatment of ringworm of the scalp that, barring excessive dosage, there is no deleterious effect on the hair.

Subsequent Treatment.—The *x*-rays cause epilation, they have no direct effect on the fungus. The fungi inhabit the hairs and when the hair falls the organisms are removed from the follicles. If any organisms remain on the scalp or in the follicles after the hair begins to regrow the disease again becomes active. Furthermore, fungi are likely to be in the house, in the clothing or on other children, so that when the hair begins to grow reinfection may occur. To avoid relapse and reinfection it is advisable to apply antiparasitic treatment to the scalp.

Between the [illegible] treatment and the defluvium and during the latter, the scalp [illegible] washed daily with soap and water. If there is considerable [illegible]ion in the diseased areas a wet dressing of aluminum acet[illegible] acid is indicated. After the defluvium the scalp may b[illegible] daily with a 1 to 5000 solution of corrosive sublimate in 50 [illegible] alcohol. One week after the defluvium it is permissible to a[illegible] a 5 per cent ointment of ammoniated mercury or preci[illegible] sulphur. Two weeks later the strength of these applications [illegible] increased. Irritating chemicals should not be employed for the [illegible] weeks after the treatment and, later, when they are used the sc[illegible]ould be watched for signs of inflammation. At the slightest sign [illegible]tion soothing applications must be at once substituted.

The noninfected children of the same family should have a daily shampoo and receive topical applications as a prophylactic measure.

When the hair begins to fall it is a good plan for the physician or nurse to apply strips of adhesive plaster to the scalp. After a few minutes these are removed with the loose hair attached (Fig. 141). They are then burned. The procedure is repeated the following day if there are any remaining hairs. The scalp should also be observed under filtered ultraviolet rays at each visit. In addition it is well to have the child wear a linen skull cap—one that can be boiled. These details are especially important when there are uninfected children in the same house.

Criterion of Cure.—The gradual disappearance of infected hairs will be noted when the hair begins to fall. The patient should not be discharged until fluorescent hairs cannot be detected under filtered ultraviolet rays in two examinations at least one week apart.

In endothrix infections the fluorescence is difficult to observe since

the infected hairs are frequently buried, and since fluorescence is not as pronounced as with Microsporon. In endothrix infections, microscopic and cultural studies should be negative on several occasions before the patient is discharged.

A mild scaliness is often noted after irradiation for tinea capitis. In the absence of fluorescent stubs and if the examination for fungi is negative this scaliness should be treated with soothing emollients or with mild salicylic acid ointment.

Relapses.—If proper precautions are taken relapses will not occur in more than 0.5 per cent. Reinfection occurs a little more frequently. Reinfection and relapses combined, even among outpatients, is not greater than 5 per cent. Relapse is more common when the infecting organism is a Trichophyton endothrix such as Trichophyton violaceum than in the more common Microsporon infections. We have observed instances in which relapse followed two and in one case three roentgen epilations, administered several months apart.

Treatment of Reinfection.—The question arises how soon after treatment can a scalp be again irradiated in case the first treatment failed to effect a defluvium or in case of relapse or reinfection?

In case of reinfection or recurrence the scalp may be again irradiated as soon as the hair is growing vigorously. This will vary from three to six months or even longer.

The authors have had numerous cases where a single small area was depilated and later the entire scalp became infected necessitating a universal defluvium. As soon as the hair began to grow vigorously in the treated area the entire scalp was irradiated. In not a single instance was there a permanent alopecia as a result of the double exposure and in a few instances the hair began to grow sooner and grew more rapidly in the original patch than upon the rest of the head (Fig. 156).

Advisability of Depilating Entire Scalp.—Many ringworm patients when first seen present only one or a few small areas of disease. In such instances, providing the parents have the intelligence, time and interest necessary to carry out the physician's instructions, it is possible to effect a cure by confining the treatment to the affected areas. As a rule, especially in dispensary work, such treatment is followed by a dissemination of the disease throughout the entire scalp. The reasons for this are:

1. At the time of the treatment all visible areas of disease are exposed. But there are likely to be infections in other parts of the scalp which have not become manifest at the time of the treatment. Such hidden infections may not even be seen when the scalp is observed under filtered ultraviolet rays.

2. Infection of other parts of the scalp may occur after the treatment in spite of intelligent prophylactic measures. The fungi may be transferred from old to new area by the fingers or by the cap or hat. The fungi may be scattered around the house.

3. Dissemination of the disease is likely to occur at the time of the defluvium

Fig 156 —Regrowth of hair two months after universal depilation with x-rays In this instance the areas in which the growth of hair is most vigorous were formerly occupied by the disease

Fig. 157 shows a scalp with a silver-dollar-sized area of ringworm A palm-sized area, including the lesion, was depilated (Fig 158)

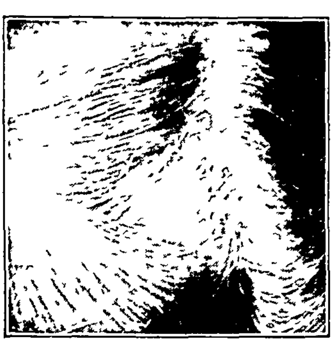

Fig 157 —A small patch of ringworm

Fig 158 —X-ray depilation of hair in and around the patch of ringworm shown in Fig 157.

Shortly after the defluvium the disease spread over the entire scalp as shown in Fig 159 In this picture one might think that the scalp

had been depilated by means of the *x*-rays Such, however is not the case Every hair on the head was broken off close to the scalp as a result of the disease The patient was then treated by the five-exposure method Subsequently the hair regrew luxuriantly and there was no further trouble Fig 160 represents a child who had several dime-sized areas of ringworm in a circumscribed area A single area was depilated as shown in the picture The remainder of the scalp remained normal and the hair regrew in the irradiated area in the usual time Lewis has recently reported a series of favorable *results obtained by epilating with x-rays only those portions of* the scalp which were infected The authors do not favor spot epilations because of frequent failures

Fig 159 —Same patient shown in Figs 157 and 158 When the hair fell out it spread over and infected the rest of the scalp The disease has caused a breaking off of all the hair close to the scalp This picture was taken before the five-exposure method was used The patient was later treated by this method with a perfect result

Hazen records the case of a private patient whose mother refused to have the whole scalp depilated Thirty-four treatments were given to various-sized patches before final recovery took place Most operators have had this same experience

Permanent Injuries Not Caused by X rays —The *x*-rays are sometimes *blamed for undesirable results that are partly, often entirely,* due to the disease In Fig 162 is shown a boy who had multiple kerions (suppurative ringworm) The permanent alopecia here is partly due

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FIG 160 — Numerous small patches of ringworm confined to one area In this instance one area of a size sufficient to cover all the disease was treated The result was perfect

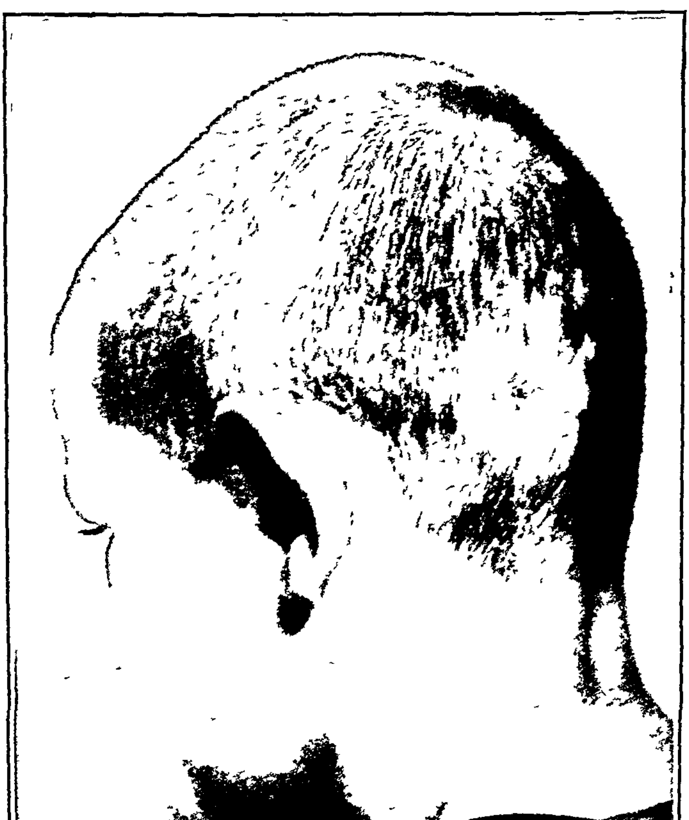

FIG. 161 — This boy, aged 9 years, had ringworm of the scalp. He was treated with caustic agents prior to his visit to our clinic He has multiple scars with permanent alopecia. The tinea was cured with x-ray epilation, but the scars and alopecia caused by the caustic remained.

to the destruction of the hair follicles by the disease and partly by the x-rays which were administered in a dispensary by the fractional method many years ago. Areas of permanent alopecia have been noted, also, in small-spored ringworm. Scars, atrophy and permanent

FIG. 162.—Atrophy and some permanent alopecia caused partly by x rays and partly by the kerion type of ringworm.

FIG. 163.—Kerion type of ringworm after depilation.

alopecia are seen in cases of tinea capitis with secondary pyogenic infection. The undesirable results are due to the superimposed infection and not to the treatment. Sometimes the use of caustic agents will cause scars of the scalp.

Treatment of Kerion.—Pustular ringworm of the scalp, of which kerion is the most severe form, usually responds satisfactorily to conservative therapeutic measures. Roentgen epilation should be used with caution, or:

1. Further local spread may result.
2. Toxic eruptions (ids) may be produced.
3. Permanent alopecia due to the infection might be considered due to *x*-rays (legal complication).

Epidemic of Tinea Capitis.—New York City and other cities throughout the United States are now in the throes of a ringworm epidemic affecting the scalps of children. The predominating organism is the M. audouini. It is the most severe epidemic ever experienced in this country There are many thousands of cases in New York City alone. In those localities in which the epidemic is best controlled, treatment has been with epilating doses of *x*-rays. During this epidemic many new drugs and combinations of drugs have been used. Ointment bases and other carriers, especially those that facilitate penetration of the fungicides, have been employed The medicinal treatment of tinea capitis caused by M. audouini has been impotent. The largest number of cures without complications has been effected with *x*-rays. We believe that the epidemic can be terminated by treating all or most of the cases with *x*-ray epilation as here outlined and by adopting "Measures to Prevent and Control an Epidemic of Ringworm of the Scalp" recently published by Lewis, Silvers, Cipollaro, Muskatblit and Mitchell.

Fractional Versus Intensive Treatment.—If one desires to do so, it is possible to obtain a defluvium by means of fractional doses. Seventy-five r applied every day or two days for four doses will usually suffice for the desired result. Occasionally it is necessary to increase slightly the size of these doses. If defluvium does not follow this routine it may be repeated in a month with larger amounts The hair usually begins to fall out about eighteen days after the last treatment. The authors do not recommend this technic. It is not used in their clinics.

Radium.—Radium has been used very little for the treatment of tinea capitis Mizzoni and Palumbo treated 132 cases with excellent results They devised an applicator consisting of a cap over which were placed tubes of filtered radium or radon at proper distances from each other and from the scalp. The exposure time is forty-eight hours.

Simpson employs blocks of soft wood or cork (2 x 2 x 1 cm.) arranged to form an applicator having a superficial area of 100 square centimeters Radon tubes are arranged on the applicator in the ratio of 1.25 millicuries per square centimeter. Screened with 1 mm silver and at a distance of 1 cc an exposure of forty-five hours may be given in three periods of fifteen hours each. Radium treatment is so impracticable that no one should consider using it.

FAVUS

Favus of the glabrous skin is somewhat more resistant to the application of topical remedies than ordinary tinea of the smooth skin. The efficacy of the x-rays in the treatment of such lesions is not known.

Favus of the scalp is a much more stubborn and serious disease than is tinea capitis. Unlike the latter it attacks persons of any age. When occurring in children it does not necessarily undergo spontaneous involution at the age of puberty. It destroys the hair follicles and, unless cured, will effect pressure atrophy of the scalp and permanent baldness.

FIG 164.—Favus of the scalp showing thick crusts that must be removed before roentgenization.

It is the consensus among dermatologists that the x rays offer practically the only satisfactory method of combating this disease when it attacks the scalp. Radium has not yet been used for this purpose.

The technic of application is exactly the same as that outlined for the treatment of ringworm of the scalp. There are, however, a few special features to be considered. In favus the scalp is likely to be covered with thick and rather adherent crusts (Fig 164). The usual procedure is to use a soap poultice for two or three days, after which the crusts can be easily removed.

Subsequent to the treatment it is very important to wash the scalp daily and as soon as defluvium occurs daily applications of a 1 to 5000 solution of corrosive sublimate should be made. The antiparasitic ointments (5 to 10 per cent ointments of ammoniated mercury or

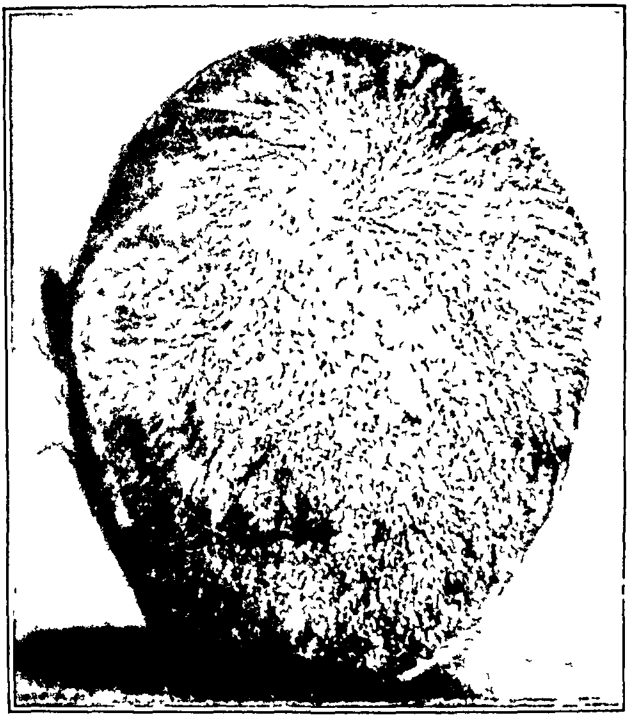

FIG 165 —Disseminated favus of the scalp before treatment Note atrophy and permanent loss of hair due to the disease Note also the so-called favus cups

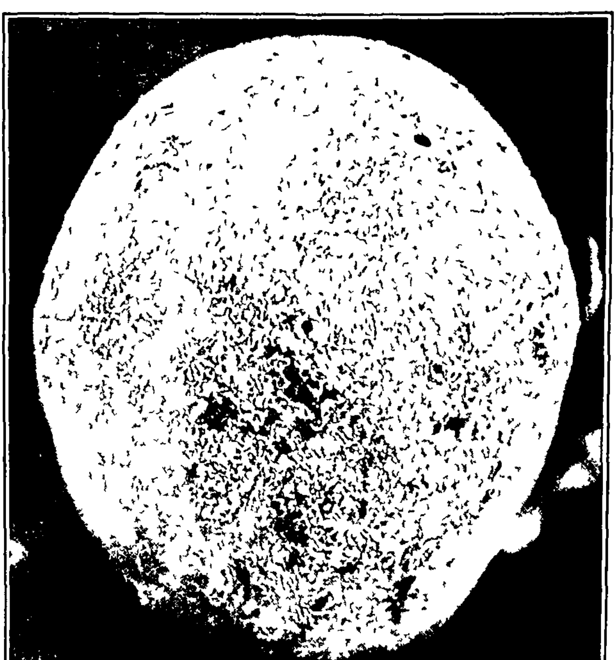

FIG 166.—Same as FIG 165, after x-ray epilation

precipitated sulphur or iodine or sodium propionate) should be begun from four to six weeks after the treatment and continued (in the absence of inflammation) for several months The scalp should be observed under filtered ultraviolet rays As soon as the hair begins to fall strips of adhesive plaster applied and removed may hasten complete depilation When only a few infected hairs remain, manual depilation by means of forceps is frequently successful in completing the cure The percentage of recurrences while higher than in tinea capitis due to Microsporon will be much less with attention to the details of after-treatment

Fig 167 —Permanent alopecia and atrophy due to favus

The dose required for epilation in cases of favus is likely to be a little larger than for tinea capitis This may be due in part to the fact that the patients are as a rule older A dose of 350 to 400 r should be given to each of five points

Before treatment the physician should explain the nature of the disease to the patient or the patient s family Otherwise the physician may be unjustly blamed for the possible atrophy and permanent baldness occasioned by the disease Fig 167 shows a case of favus that has been cured by means of the x-rays The entire scalp was depilated The atrophy and baldness are due to the disease and were present before the x-ray treatment was given

To avoid the sequelæ of the disease it is necessary to make an early diagnosis and to apply x-ray treatment before permanent injury to the scalp has occurred

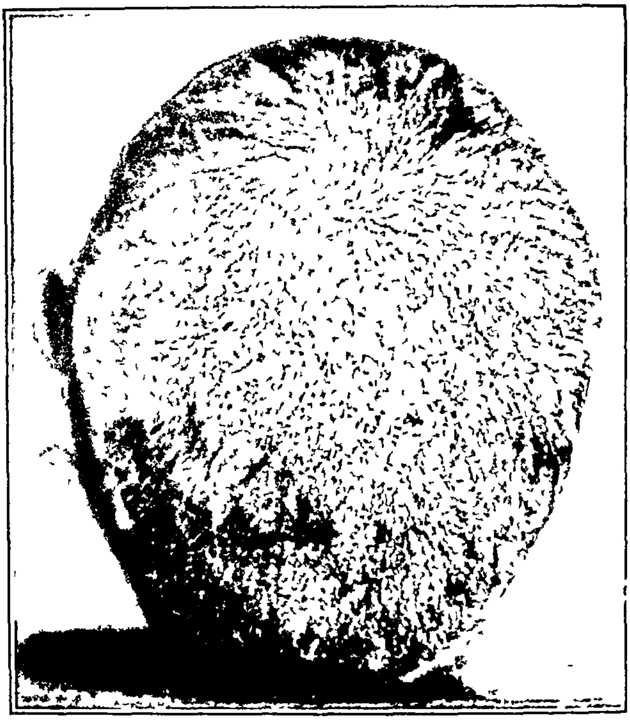

Fig. 165—Disseminated favus of the scalp before treatment Note atrophy and permanent loss of hair due to the disease Note also the so-called favus cups

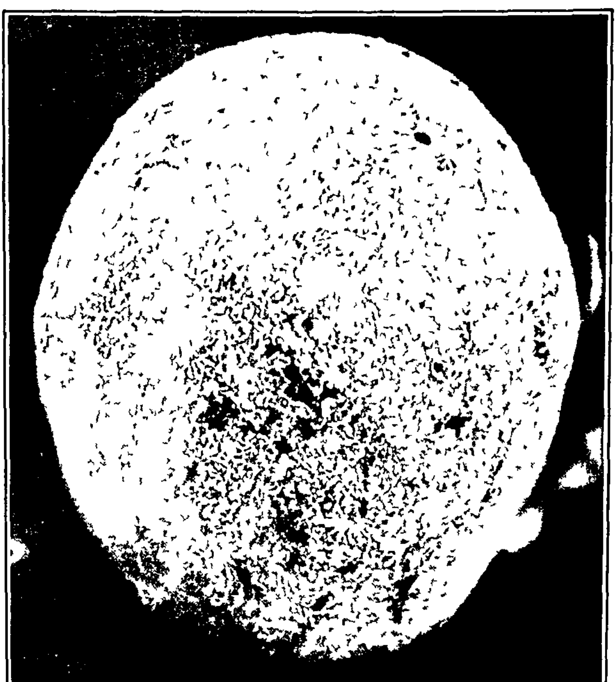

Fig 166.—Same as Fig 165, after x-ray epilation

precipitated sulphur, or iodine or sodium propionate) should be begun from four to six weeks after the treatment and continued (in the absence of inflammation) for several months. The scalp should be observed under filtered ultraviolet rays. As soon as the hair begins to fall, strips of adhesive plaster applied and removed may hasten complete depilation. When only a few infected hairs remain, manual depilation by means of forceps is frequently successful in completing the cure. *The percentage of recurrences, while higher than in tinea* capitis due to Microsporon, will be much less with attention to the details of after-treatment.

Fig. 167.—Permanent alopecia and atrophy due to favus.

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To avoid the sequelæ of the disease it is necessary to make an early diagnosis and to apply x-ray treatment before permanent injury to the scalp has occurred.

TINEA BARBÆ.

(Ringworm of the Beard.)

When the causative organism is Trichophyton gypseum, there are usually boggy infiltrations with follicular pustules. The tendency is for spontaneous cure, so conservative measures (wet dressings and later fungicidal preparations) should be used. Roentgen epilation is seldom advisable with these patients. If the fungus responsible is a Trichophyton endothrix such as Tr violaceum there is only moderate inflammatory reaction present. A depilating procedure is usually advisable If there are only one or two areas, manual depilation may be sufficient to effect a cure. Roentgen epilation, however, may be necessary if the lesions are scattered over the entire bearded region

Technic.—The technic of application will depend upon the extent of the affected surface. If there are one or a few scattered lesions it will suffice to irradiate the individual lesions A cluster of lesions may be treated in the same manner. At times it is necessary to irradiate one side of the face and neck and even the entire bearded region. The parts of the face and neck occupied by the beard constitute an exceedingly irregular surface and yet it is necessary to apply an equal amount of radiation to the entire affected region This may be done by dividing the bearded region into a number of small areas by means of a skin pencil. Each area is then irradiated in succession, care being taken not to expose the same area twice and to avoid overlapping of the treatments. For many reasons this is an unsatisfactory and obsolete method.

Kienbock's Method.—Four exposures are necessary

1 Anode placed directly over the center of the upper lip.
2 Anode placed directly over the angle of the right mandible
3. Anode placed directly over the angle of the left mandible.
4. Anode placed over the center of the chin in such manner that an imaginary line from the target to the center of the chin will be almost but not quite at right angles with a similar line running from the center of the upper lip to the target with the tube placed in the first position (Fig 168) To obtain this position it is necessary to have a specially constructed headrest or to place a sandbag or a block of wood under the back of the neck with the patient lying on his back A folded pillow will not answer the purpose because it may allow change of position during the exposure As shown in the figure the head must be thrown well back.

Distance—A distance of 8 inches (20 cm) is recommended It is very important that the target-skin distance be the same for each exposure. It is equally important that the head remain steady during the exposures

Dose.—Unfortunately the question of dosage is not so simple as when treating the scalp On the scalp an epilating dose will effect a defluvium without provoking an erythema. On the face an epilating

dose (300 r) is very likely to cause a first-degree reaction and even a mild first-degree reaction may be followed several months later by telangiectasia. Furthermore in many instances, it requires a larger amount of radiation to depilate the beard than it does to depilate scalp hair. We are not in favor of applying a full epilating dose at one sitting in the treatment of tinea barbæ. One can try 225 r and the result may be a defluvium or a cure without defluvium. Experience has shown that with properly spaced fractional doses it is possible to depilate the beard without effecting an erythematous reaction. Such treatment consists of 75 r every two or three days for from four to eight treatments. In cases when the hair has not fallen out as a result of a total dose of 450 to 600 r (1½ to 2 skin units) and there is no evidence of erythema one may proceed cautiously until the hair does fall.

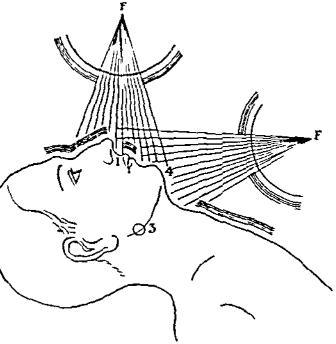

FIG 163 —Showing the angles of incidence for treatment of sycosis vulgaris and tinea barbæ (Kienbock.)

It is so difficult to obtain a defluvium of the beard with x rays without danger of sequelæ that we advise against the method except when other methods fail and then it is advisable to have a consultation with division of responsibility for medicolegal reasons. The extensive form of the disease is so rare that it is seldom necessary to epilate the entire bearded area. Because of the danger of radiodermatitis and the subsequent development of carcinoma the authors recommend that topical remedies and manual epilation be employed to control tinea barbæ.

Protection.—The entire head, above the bearded region, is to be protected with lead foil or other suitable material. The same is true of the chest and shoulders and the unaffected portions of the anterior and lateral surfaces of the neck. The mucous surfaces of the lips should be carefully protected. This is important If the hairy portion of the upper lip is not involved, it too should be covered with protecting material.

The four-exposure method does not provide an absolute equalization of dosage for such an irregular surface but it answers practical requirements

Additional Treatment—Care must be taken not to allow the use of irritating lotions or ointments, immediately before, during or immediately after the treatment The parts may be bathed daily with soap and water and shaving is permissible If the entire bearded region has been irradiated, mild antiparasitic salves (3 to 5 per cent ammoniated mercury or precipitated sulphur) may be applied a week or two after the defluvium providing they do not provoke inflammation. If isolated areas have been treated the rest of the bearded region should receive antiparasitic treatment, care being taken to avoid the irradiated parts

When defluvium occurs the result is usually a cure. Hairs infected with Trichophyton endothrix (violaceum) exhibit fluorescence of a dull bluish-white when observed in filtered ultraviolet rays Inspection in this way is of value in determining cure. Reinfections and relapses are not common If the epilating dose is administered at one sitting the hair falls out in eighteen to twenty-one days. When the treatment is administered fractionally, defluvium usually occurs four to five weeks subsequent to the first exposure. The quality of radiation is of no great importance except that it is possible that with filtered rays there is a little more latitude between the amount necessary for depilation and the amount that will provoke an erythema

Radium—Radium has been used by Simpson and others for isolated patches and for the entire bearded region. It is not a method of treatment that is likely to be popular with dermatologists or roentgenologists, except for the treatment of one or a few small discrete lesions For a single lesion, a 25 mg tube, at a distance of $\frac{1}{2}$ inch, screened with 0 5 mm silver, 1 mm brass and 3 mm. rubber, the dose will be about four hours

ONYCHOMYCOSIS.

(FAVUS AND RINGWORM OF THE NAILS)

Roentgenization is of somewhat uncertain value in this exceedingly recalcitrant disease The difficulty of ascertaining its real value is largely a matter of diagnosis Cultural, or at least microscopic, verification is usually necessary to support a clinical diagnosis and it is unwise to record statistics relative to the treatment of onychomycosis without such confirmation.

There is not the slightest question regarding the efficacy of the x rays in some cases of onychomycosis. We have a record of 96 cases of onychomycosis that have been roentgenized. In 30 cases the diagnosis was verified by microscopic examination. Of these 10 cases made a prompt recovery, 8 cases recovered after prolonged treatment (18 cures) and 12 cases failed to improve. In most of the cases without microscopic confirmation but which were probable cases of onychomycosis, the results were unsatisfactory. The percentage of cures for the entire series was small. Efficacy depends somewhat on the particular fungus. Nails infected with Trichophyton gypseum are more readily cured than when the causal organism is Trichophyton purpureum.

In a few instances the rapidity of cure was astonishing as not more than six or eight fractional applications were administered. Wise in a verbal communication tells of 3 similar cases. In other instances as many as 10 intensive treatments were given before the desired result was obtained.

We are not prepared to state which is the better treatment—intensive or fractional—insofar as concerns efficacy. Other forms of treatment are so difficult of administration and so disappointing in results that it seems advisable to give the method a trial.

Technic.—Before applying the x rays the nails should be prepared for the treatment. They should be soaked for an hour or two in hot soapsuds, then scraped with a knife.

If there is no paronychia only the nail should be irradiated. If there is paronychia it is necessary to expose the inflamed skin for ¼ inch beyond the affected portion.

It is not wise to evoke an erythema of the skin around the nail, therefore fractional or semi-intensive doses are indicated. If the nail is thick and it is not necessary to irradiate the surrounding skin, intensive doses may be administered. Because the infection is under the skin (paronychia) and in and under the nail (onychia) filtration may be of advantage.

The disease often involves several nails. It is possible so to arrange the hands that from two to eight nails can be treated with one exposure. By closing the hands and placing the knuckles together the thumb nails are approximated. The nails of the index, middle and ring fingers of both hands can be placed on the operating table in such manner that they will fall well within the field of radiation and therefore may be exposed at one time. With the exception of the nails of the great toes, which are approximated and treated simultaneously, it is customary to irradiate each toe nail separately.

It is not known how the x rays effect a cure in ringworm of the nail. There is no sudden loss of the nail after an intensive treatment followed by a period of quiescence and then regeneration as is seen in temporary alopecia, but, nevertheless there may be an analogy. The authors have seen the shedding of a nail after an intensive treatment, but the process

is very slow, the old nail being gradually expelled as the new one grows. It is possible, therefore, that the efficacy of the x-rays lies in their ability to arrest development temporarily, which is followed by the shedding of the old nail as the new one develops, and that this phenome-

FIG. 169.—Ringworm of the nails before roentgenization.

FIG. 170.—Same as Fig. 169, after four intensive treatments.

non is so gradual that it is usually overlooked. On the other hand, cases have been observed where the disease disappeared, apparently as a result of roentgen therapy, and there was, at no time, any noticeable arrest of growth. In these instances the older and diseased portion

of the nail was gradually cut away and the newer growth remained healthy.

Antiparasitic remedies should not be employed two weeks previously, during, nor for two weeks subsequent to roentgen treatment, unless of very mild strength, such as a solution of corrosive sublimate 1 to 5000 or a 3 per cent ointment of ammoniated mercury or precipitated sulphur. The authors dispense with these remedies entirely and depend upon soap and water for cleanliness and prophylaxis.

Figs. 169 and 170 show a case of onychomycosis before and after roentgen treatment. The clinical appearance is more suggestive of dystrophy but spores were found in the scrapings, and cultures were obtained from scrapings from the nail of the index finger of the right hand. These spores resembled, morphologically and culturally, those of ringworm. There were no lesions of psoriasis or eczema on the body. The duration was one year.

Radium.—We have not employed radium in the treatment of onychomycosis nor have we seen reference to such treatment in the literature. Radium rays will certainly be fully as efficacious as will the x rays if properly applied. On account of the convexity of the nails a flat applicator is not suitable unless placed at a considerable distance. The indicated treatment is a 25 mg. tube screened with 0.5 mm. silver, 1 mm. brass and 3 mm. rubber, placed over the nail at a distance of ½ inch for from two to four hours once every month or two, for several treatments if necessary.

TINEA OF THE GLABROUS SKIN

Roentgen therapy is of little value in ordinary ringworm of the glabrous skin—tinea circinata, etc., because these lesions respond quickly and satisfactorily to topical remedies. When ringworm fungi produce lesions of eczematous type, irradiation may be of considerable service. Eczematoid ringworm, eczema marginatum, dermatophytosis, etc., will be found in the chapter on Eczema.

MONILIASIS

Of the localized cutaneous forms of monilia infections, chronic paronychia, so common among middle-aged overweight housewives, usually responds well to four or five weekly fractional (75 r) x ray treatments. However recurrences are common unless the patient can keep her hands out of water. Roentgen treatment of perleche, erosio interdigitalis blastomycetica and of the other intertriginous forms of moniliasis has not proved of much help in their management. It should be kept in mind that the presence of a manifestation of monilia infection is frequently possible only because of some underlying systemic disorder. For this reason all such patients should receive a thorough physical examination with particular emphasis on the detec-

tion of a real or incipient diabetes mellitus or of avitaminosis. The generalized variety of moniliasis may be ameliorated by the use of a few doses of x-rays. Most cases respond satisfactorily to treatment with gentian violet

ACTINOMYCOSIS.

Actinomycosis is a rare disease and not many examples of the condition have been treated with the x-rays. From personal observation and a review of the literature, we are of the opinion that the x-rays or radium rays are not only indicated in this stubborn and serious disease but that such treatment is superior to any other. Unfortunately most of the reports found in the literature state that both potassium iodide and x-rays were used and while the opinion prevails that the involution of the ulcers, sinuses and nodules was due to the x-rays, yet the fact that potassium iodide was administered makes the cause of the recovery a little uncertain. The fact, however, that a few cases of actinomycosis have been cured with x-rays (or radium) alone shows that such treatment is efficacious. The sulfur group of drugs are beneficial in the treatment of actinomycosis

Ormsby successfully treated 3 cases of actinomycosis with a combination of iodide of potassium internally and x-rays locally. Bevan makes a similar report. Harris cured a severe case of actinomycosis of the neck by the combined treatment. These authors are convinced that the x-rays cause the involution of the cutaneous lesions.

Zeisler failed to cure a case with iodide of potassium. The lesions disappeared apparently under the influence of the x-rays but the patient also took copper sulphate internally. Steinkamm, Prickul, and Heyerdahl report good results. Heyerdahl avoided topical and internal remedies and employed only gamma rays of radium in 21 cases all of which were cured.

Figs. 171 and 172 show a patient with actinomycosis, before and after roentgen treatment. One intensive dose of x-rays was administered. Improvement began in two weeks and the eruption disappeared in a month. A second intensive dose was given at this time as a prophylactic. There was no local recurrence and no extension of the disease to other parts. The patient received no treatment other than x-rays. The clinical diagnosis was confirmed by microscopic examination.

Pels reports a case of actinomycosis of the hand that was clinically cured after receiving three intensive x-ray treatments, the radiation being filtered through 0.5 mm. of aluminum. The patient, however, also received iodide of potassium internally.

Engelstad obtained an apparent cure in a case of abdominal actinomycosis by means of treatment with radium. Archer and Barker favor the employment of massive doses of iodides, roentgen irradiation and surgery for drainage. Stewart-Harrison treated 22 cases of proved actinomycosis of the head and neck by various methods of roentgen

therapy He concluded that a protracted fractional treatment (daily doses with copper filtration and up to a total of 3000 to 4000 r within one month) is the most effective technic he has used Since the lesions are deep-seated filtered radiation should theoretically give the best results Filtration is of course, necessary when radium is used as only the gamma rays should be utilized

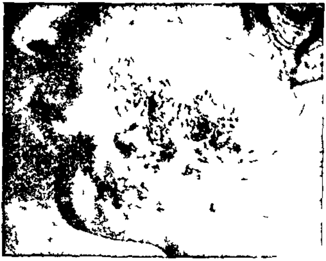

FIG 171 —Actinomycosis before *x* ray treatment

FIG 172 —Same patient shown in Fig 171 after two subintensive *x* ray treatments

BLASTOMYCOSIS

What has been said under actinomycosis answers pretty well for blastomycosis It is not quite so rare so there are a larger number of recorded cases treated with *x* rays So far only the cutaneous lesions have been treated It would be very interesting to learn the effect of irradiation of the visceral lesions

Pusey, Gilchrist, Ormsby, Fischkin, Zeisler and others have cured cases of cutaneous blastomycosis with a combination of potassium iodide and x-rays Ormsby and Desjardins completed several cures with the x-rays Montgomery, Oulmann, Knowles, and Pusey recorded cases where there was great improvement following the use of x-rays without any other treatment The patients were presented at society meetings and recorded before the cure was completed.

Davis presented a patient afflicted with blastomycosis before the Philadelphia Dermatological Society. Iodide of potassium proved useless in this case. The lesions, when the patient was presented, had almost disappeared as a result of roentgenization. Montgomery records a case of cutaneous and systemic blastomycosis. The cutaneous lesions disappeared under x-ray treatment but they recurred and the patient died. Winfield presented an interesting case of blastomycosis before the New York Dermatological Society. Iodide of potassium had proved useless. The eruption disappeared entirely under the influence of the x-rays. Ravogli found x-rays more useful than iodide of potassium. Simpson records a complete cure of a case of cutaneous blastomycosis with radium.

We have cured several cases of localized cutaneous blastomycosis with both fractional and intensive doses of x-rays. There was a relapse in only one case and in another the skin lesions were cured and two years later the patient developed pulmonary lesions and succumbed In most of the cases the lesions disappeared as a result of one or two subintensive treatments or from six to twelve fractional applications. In one instance, a farmer with a lesion occupying the entire dorsal surface of one hand, the treatment was apparently ineffectual After receiving two subintensive treatments the patient returned home discouraged A letter was received from him in three weeks stating that the lesion had disappeared shortly after returning home No other treatment had been given.

All the cases so far treated with x-rays have been given both filtered and unfiltered radiation As a rule, cutaneous blastomycosis is not so deep-seated as are the lesions of actinomycosis It is questionable if a filter would add to the value of the treatment unless the lesions are unusually deep-seated or when the viscera are involved

SPOROTRICHOSIS.

As a rule little difficulty is experienced in obtaining a satisfactory involution of the lesions in the treatment of this disease by means of the internal administration of iodides If a considerable degree of fibrosis is present in an individual lesion, the use of semi-intensive roentgen therapy is indicated J. B Shelmire and E. D. Crutchfield, in verbal communications, reported successful involution of lesions of sporotrichosis with x-rays without the use of iodide of potassium or other remedies. Lain obtained good results with a combination of

iodine internally and unfiltered x-rays locally but not with x rays alone In a case of sporotrichosis recently observed a prompt cure followed irradiation of the lesions and the ingestion of potassium iodide

GRANULOMA COCCIDIOIDES

Jacobson employed roentgen therapy in conjunction with injections of colloidal copper and obtained some remissions and apparent cures He mentioned that others have obtained favorable results from the administration of x-rays together with tartar emetic intravenously

BIBLIOGRAPHY

ABRAMOWITZ L W Thallium Medication in Tinea Capitis and Other Dermatoses Requiring Epilation New York State Jour Med 29 253 1929

ADAMSON H G A Simplified Method of X Ray Application for the Cure of Ringworm of the Scalp Kienbock s Method Lancet 1 1378 1909

ARCHER A W and BARKER W A The Therapy of Actinomycosis Am Jour Roentgenol 30 508 1933

BEVAN A D Kocher s Case of Resection of Jaw Ann Surg 41 626 1905

BUSCHKE A Experimentelle Beitrag zur Kenntnis der Alopecie Berl klin Wchnschr 37 1235 1900

BUSCHKE A and LANGER E Die kombinierte Thalliumrontgenepilation Dermat Wchnschr 85 1390 1927

CICERO R E El Tratamiento de las Tiñas por el Acetato de Talio Rev med d Puebla 1 177 1919

COSTELLO M J and LUTTENBERGER L A Fluorescence With the Wood Filter as an Aid in Dermatologic Diagnosis New York State Jour Med 44 1778 1944

DAVIS C N A Case of Blastomycetic Dermatitis Jour Cutan Dis 24 90 1906

DESJARDINS A U Roentgenotherapy and Diathermy in Blastomycosis Am Jour Roentgenol 14 14 1925

ENGELSTAD R B Radiumbehandlung von abdominaler Aktinomykose Strahlentherapie 47 547 1933

EPSTEIN S Die Bedeutung der Ueberschneidungen fur das Zustandekommen von Rontgenspatschäden in der Oberflächentherapie Arch f Dermat u Syph 168 548 1933

——— The Importance of Overlapping in Irradiation of the Scalp With Comments on the Tolerance of the Skin for Soft Rays Brit Jour Dermat and Syph 48 1 1936

FELDEN B F Epilation With Thallium Acetate in the Treatment of Ringworm of the Scalp in Children Arch Dermat and Syph 17 182 1928

FISCHKIN Quoted by Ormsby

FREUND L Nachtrag zu dem Artikel Ein mit Rontgen Strahlen behandelter Fall von Naevus pigmentosus piliferus Wien med Wchnschr 47 856 1897

FREUND L and SCHIFF E Weitere Anwendungsgebiete der Radiotherapie Fortschr a d Geb d Rontgenstrahlen 3 109 1900

GILCHRIST T C Some Additional Cases of Blastomycetic Dermatitis Jour Cutan Dis 22 107 1904

GUTMANN C Bemerkungen zur Rontgenbehandlung der Mikrosporie und Trichophytie der Kinderkopfe und zur Pilzflora der letzteren Affektion Dermat Wchnschr 73 1123 1921

HAMPSON W The Epilation Dose Arch Roentg Ray 16 85 1910–1911

HARRIS F Actinomycosis of the Neck Jour Cutan Dis 34 616 1916

HAZEN H H The Roentgen Ray Treatment of Tinea Tonsurans Ibid 37 307 1919

HEYERDAHL S A Four Cases of Actinomycosis Treated by Radium Forh med Selsk 1915 p 175 Abstract Arch Radiol and Electroth 21 305 1917

——— Actinomycosis of the Face and Neck Treated with Radium Brit Jour Radiol 31 1 1926

INGRAM J T Thallium Acetate in the Treatment of Ringworm of the Scalp Brit Med Jour 1 8 1932

JACOBSON H P Fungous Diseases Baltimore Charles C Thomas 1932 p 245

KIENBOCK, R Ueber Radiotherapie der Haarerkrankungen, Arch f Dermat u. Syph., 83, 77, 1907, Abstract, Arch Roentg Ray, 12, 12, 1907.
KINNEAR, J A Note on the Effect of the Angle of Incidence upon the Dose of X-Rays Absorbed by the Skin, Brit Jour. Dermat and Syph, 47, 202, 1935
KNOWLES, F C A Case of Blastomycosis, Jour Cutan. Dis, 24, 183, 1906
LAIN, E S. Sporotrichosis, Jour Oklahoma Med. Assn, 13, 41, 1920
LANE, C G Tinea Capitis—Roentgen Ray Treatment, Boston Med. and Surg Jour, 183, 673, 1920
LANE, C G, and CRAWFORD, G M Measurement of Roentgen Therapy for Tinea Capitis, Arch Dermat and Syph, 37, 62, 1938
LEWIS, G M Ringworm of the Scalp Curability, Without Depilating Measures, of Infections Caused by "Animal" Microsporons, Am Jour. Med Sci, 189, 364, 1935
LEWIS, G M., and HOPPER, M E Ringworm of the Scalp III. Clinical and Experimental Studies in Types of Infection Resistant to Treatment, Arch Dermat and Syph, 35, 460, 1937
———— Introduction to Medical Mycology, 2d ed, Chicago, The Year Book Publishers, Inc, 1943
———— Ringworm of the Scalp VI Successful Use of Roentgen Rays to Epilate Local Areas of Infection, Arch Dermat and Syph, 49, 107, 1944
LEWIS, G M, SILVERS, S H, CIPOLLARO, A C, MUSKATBLIT, E., and MITCHELL, H H Measures to Prevent and Control an Epidemic of Ringworm of the Scalp, New York State Jour Med, 44, 1327, 1944
MACKEE, G M, and ANDREWS, G C Time-Saving Devices for the Roentgen-Ray Treatment of Ringworm and Favus of the Scalp, Am Jour. Roentgenol., 9, 746, 1922.
MACKEE, G M, *CIPOLLARO, A C, and MUTSCHELLER, A* The Treatment of Tinea Capitis with Roentgen Rays and Its Practical Application in Current Epidemics This Article Contains a Description of the 4-point Method of Scalp Epilation, Arch Dermat and Syph In press, 1946
MACLEOD, J. M H The *X* Ray Treatment of Ringworm of the Scalp, With Special Reference to the Risks of Dermatitis and the Suggested Injury to the Brain, Lancet, 1, 1373, 1909
MAZZONI, L, and PALLUMBO, V La depilazione con il radium applicata alla cura dei tignosi, Policlinico, (Sez prat) 28, 503, 1921
MOLESWORTH, E H, and RIDDLE, A R The Effect of the Angle of Incidence Upon the Dose of *X*-Ray Absorbed by the Skin, Brit Jour Dermat and Syph, 47, 152, 1935
MOLESWORTH, E H, RIDDLE, A R, ROXBURGH, A C, and KINNEAR, J Debate on *X*-rays The Effect of the Angle of Incidence, Brit Jour Dermat and Syph, 47, 405, 1935
MONTGOMERY, F H A Case of Cutaneous Blastomycosis Followed by Laryngeal and Systemic Tuberculosis, Jour Cutan Dis, 21, 19, 94, 1903
———— Report of a Case of a Systemic Blastomycosis, Including Autopsy and Successful Animal Inoculations, Ibid, 25, 393, 1907
ORMSBY, O S, and MONTGOMERY, H Diseases of the Skin, 6th ed, Philadelphia, Lea & Febiger, 1943
OULMANN, L Blastomycosis, Jour Cutan Dis, 29, 456, 1911
PELS, I R Primary Actinomycosis of the Skin Report of a Case Involving the Hand, Ibid., 37, 740, 1919
PRIKUL, A Ueber die Behandlung der Aktinomykose mit Rontgenstrahlen, Deutsch Ztschr f Chir, 166, 414, 1921
PUSEY, W A Blastomycosis on Cheek and Neck, Jour. Cutan Dis, 33, 389, 1915
PUSEY, W A., and CALDWELL, E W The Practical Application of the Roentgen Rays in Therapeutics and Diagnosis, 2d ed, Philadelphia, W B Saunders Company, 1904, p 430
RAVOGLI, A Some Further Observations on Blastomycosis, Lancet-Clinic, 105, 489, 1911
SABOURAUD, R J A Maladies du cuir chevelu III Les maladies cryptogamiques Les Teignes, Paris, Masson et Cie, 1910
———— Sur l'existence fréquente d'un soi-disant eczéma des doights et des orteils, du à *l'épidermophyton inguinale*, Am de dermat et syph, 1, 289, 1910
SABOURAUD, R, and NOIRÉ, H Traitement les teignes tondantes par les rayons X à l'Ecole Lailler (Hôpital St Louis), Presse méd, 2, 825, 1904
SABOURAUD, PIGNOT, and NOIRÉ La radiothérapie des teignes a l'école Lailler en 1904, Ann de dermat et syph, 6, 80, 1905

Schreus H T and Proppe A On the X Ray Epilation of the Scalp Brit Jour Dermat and Syph 48 113 1936

Shanks S C X Ray Treatment of Ringworm of the Scalp A Survey of 2400 Cases Ibid 43 477 1931

Simpson F E Radium in the Treatment of Blastomycosis With Report of a Case Jour Am Med Assn 62 844 1914

——— Radium Therapy St Louis C V Mosby Company 1922 p 295

Steinkamm J Die Strahlenbehandlung der Aktinomykose zugleich einige Bemerkungen über die Strahlenbehandlung der Trich prof Strahlentherapie 12 512 1921

Stewart-Harrison R The Radiation Treatment of Actinomycosis Brit Jour Radiol 7 98 1934

Templeton H J A Point in Roentgen Technic for Epilation of the Scalp Arch Dermat and Syph 33 537 1936

Thallium Acetate Poisoning (Editorial) Brit Med Jour 1 25 1934

Torok L and Schein M Die Radiotherapie und Actinotherapie der Hautkrankheiten Wien med Wchnschr 52 847 899 1012 1064 1123 1902

Whitfield A Eczematoid Ringworm of the Extremities and Groin Brit Jour Dermat 23 375 1911

Williams A W A Note on Certain Appearances of X Rayed Hairs Ibid 18 63 1906

Winfield J M Case Report Blastomycetic Dermatitis Jour Cutan Dis 28 139 1910

Zeisler J Notes on a Case of Actinomycosis Ibid 24 510 1906

——— Blastomycosis Ibid 28 462 1910

CHAPTER XXVIII

ECZEMA

THE conditions discussed in this chapter are:

1 Dermatitis Venenata.
2. Dermatophytosis
3 Dermatophytid.
4 Infectious Eczematoid Dermatitis
5. Neurodermatitis and Lichenification.
6. Chronic Lichenoid, Discoid Exudative Dermatosis.
7. Eczema of Infants and Children
8 Dermatitis Seborrheica
8 Dermatitis Hemostatica.
10. Intertrigo.
11. Regional Eczema.
12. Eruptive Types of Eczema

The x-rays have been used successfully in the treatment of eczema almost from the very beginning of roentgen therapy. Ullmann recommended such treatment for chronic eczema as far back as 1900 Jutassy, Schiff and Freund, Hahn, Sjogren and Sederholm, Albers-Schonberg, Mackey, Scholtz, and others, found that subacute and chronic eczematous lesions disappeared as a rule with great rapidity as a result of a few mild x-ray treatments Williams, Meek, Pusey, Allen, Hyde, Montgomery and Ormsby, Robinson, and Zeisler were the first to employ x-rays for this purpose in the United States. Pusey and Williams determined that irradiation was useful in acute as well as subacute and chronic eczema.

In the past thirty years it seems that almost every dermatologist and roentgenologist has written on this subject Certainly the literature is voluminous, and for the most part the articles are only of historical interest There are advocates of mild treatment and advocates of intensive treatment. Many of the early workers did not hesitate to produce reactions. Very early the opinion was unanimous that in most instances the lesions of eczema disappeared rapidly under the influence of very small doses and in practically all cases the itching was relieved quickly. At first it was thought that the clinical cure might be permanent but later it was found that recurrences were common.

Modern writers are perhaps even more enthusiastic than were the earlier authors. The results are better today because of greater ability to select cases and because modern technic and knowledge preclude injury. All modern textbooks on dermatology and roentgen therapy call attention to the efficacy of irradiation in the treatment of eczema, especially the chronic types

Modern Conception of Eczema.—The word eczema conveys very little information to the modern dermatologist. Years ago the term included what are now a number of separate clinical entities and the disease was thought to be always of internal origin. Finally, clinicians of long experience realized that the disease could be split into several clinical types, and with increased knowledge relative to etiology and a better interpretation and classification of symptomatology, one entity after another has been separated until now there is very little left to which the word eczema can be applied. To most dermatologists today the word eczema means an eruption that at some stage of its evolution is exudative, either clinically or histologically. It begins with erythema. If evolution is uninterrupted, this is followed by edema and often by vesiculation, erosion and exudation and, finally, by crusting and desquamation. The development may be slow or rapid, any one stage may be evanescent or prolonged, or the disease may end at any stage either spontaneously or because of therapy.

The first entities to be given a separate name were intertrigo, neurodermatitis, seborrheic dermatitis, and dermatitis venenata and its subdivisions. Then came infectious eczematoid dermatitis and the many varieties of eczematoid ringworm.

In the manner in which the word eczema is used, dermatologists can be divided roughly into three groups. One group considers that most eczematous eruptions must have an external causative or exciting factor—chemicals, bacteria, fungi, heat, light, friction, uncleanliness, excessive use of soap and water, traumatism, purulent, mucopurulent and even mucous discharges, etc. They admit general internal factors such as sensitization, impoverished local circulation, etc. They prefer to discontinue the use of the term eczema and substitute the word dermatitis with a qualifying adjective.

A second group prefers to use the word eczema for every eczematoid eruption regardless of etiology, adding adjectives to designate the type. They believe that some cases of eczema are due to internal causes, *some to external causes and some to both internal and external causes.*

A third group would give new names to eruptions that have been definitely separated from the old eczema and to use the term dermatitis to designate eczematous eruptions of local or external etiology, reserving the word eczema for eruptions supposedly due to internal disturbances.

There is, therefore, some confusion relative to the terms eczema and dermatitis, also as to the etiology of the various eruptions comprising the eczema group. Hence we hear of occupational eczema, contact dermatitis, dermatitis venenata, intertrigo, eczema intertrigo, eczematoid ringworm, parasitic eczema, eczema marginatum, dermatophytosis, etc.

Now as a matter of fact it makes little difference what we call a thing as long as we understand its nature and cause. A name is for the purpose of designation and, of course, it is preferable that we should

all be agreed on the name selected to represent an entity. At present, however, this is impossible in the case of eczema

It will suffice for our purpose to know that the eczema of our forefathers has been and continues to be split into entities or varieties, the splitting being due to a better interpretation of eruption characteristics and increased knowledge relative to etiology. It should be obvious from the foregoing and it will be more obvious from what follows, that much is left to the imagination when one states that eczema, acute or chronic, is benefited or cured by irradiation—we should be more specific; we should state when possible the variety of eczema or dermatitis that is being treated For convenience the authors have included in this chapter conditions that used to be called eczema. They may now be called the eczema group of skin diseases, the eczematoid dermatoses, varieties of eczema, or clinical entities.

DERMATITIS VENENATA.

Dermatitis venenata (occupational or trade eczema or dermatitis; contact dermatitis) may be defined as a reaction of the skin caused by external contact with substances to which the skin or the patient has become sensitized or allergic. The eruption may be acute, subacute, or chronic The chronic type may develop insidiously or it may be preceded by acute or subacute symptoms. It is likely to be associated with frequent and severe acute exacerbations. The behavior of the disease depends upon the nature of the causative agent, the frequency of contact, and the degree of susceptibility.

Dermatitis venenata may be caused by an exceedingly large number of substances, all of which are enumerated in textbooks on dermatology.

The eruption caused by some of these substances is characteristic and may be recognized by the character of the elementary lesion, the sites of predilection, the course, etc. Unfortunately this is true in only a relatively few cases, although an experienced dermatologist will usually find one or more features that will lead to a correct diagnosis

The x-rays are not indicated in the majority of cases of dermatitis venenata If the case is properly diagnosed and the cause removed the eruption as a rule will disappear quickly. At times, however, the diagnosis is exceedingly difficult; often quite impossible until after prolonged observation Such cases have provided the author with material for study in connection with x-rays Involution of acute eruptions and acute exacerbations is often hastened and pruritus is lessened by a few doses at weekly intervals consisting of from 38 to 75 r However, as good, if not better, results can be obtained by the proper choice and use of dermatologic remedies In any event, the detection and removal of the cause is the main requisite, otherwise the eruption is likely to persist or to recur repeatedly.

Technic.—We employ fractional treatment (75 r unfiltered once weekly). If there are only one or two lesions the normal skin should be protected. If the eruption is extensive the rays must, of course, be allowed to spread over the affected parts. Isolated areas of normal skin need not be protected as there is no danger from such small doses. If the disease does not disappear in from three to six weeks it is inadvisable to continue the treatment. Local applications containing such chemicals as tar, mercury, sulphur, salicylic acid, etc., are contraindicated unless they are very weak.

INFECTIOUS ECZEMATOID DERMATITIS

This disease, described by Engman and Mook, and by Fordyce (secondary eczema) may be defined as a dermatitis secondary to a discharging ulcer, sinus, boil, abscess, etc. The eruption may be dry but it is more likely to be exudative, crusted or pustular. It spreads by peripheral extension and, perhaps, by auto inoculation. The disease is supposedly caused by sensitization to bacterial products. It may complicate ecthyma, bed sores, truss sores, breast abscess, some other variety of exudative dermatitis, etc. Discharges from the nose, eyes, ears, anus, etc., may be the starting point of the disease.

Results of Irradiation.—It is possible to obtain satisfactory results if the cases are properly selected and roentgenization is associated with intelligent dermatologic treatment. We have seen eruptions begin at the margin of an ulcer and later involve most if not all of the body surface. In cases of this kind, when the symptoms are acute—edema, erythema, exudation and burning pain—*x*-rays have been of little if any benefit until the condition has become subacute. If the eruption does not disappear after subsidence of the acute symptoms either spontaneously or as a result of topical and constitutional therapy roentgenization may be of distinct value.

In the less acute types, when the eruption is papular or squamous, with or without more or less exudation, and severe itching, *x* rays may prove more efficacious than any form of treatment.

Localized dermatitis secondary to discharge from a cavity such as the ear, even when of the very acute type will often yield to irradiation.

To obtain a permanent cure it is of course essential that the type and cause of the dermatitis be recognized and steps taken to remove the latter.

Technic.—The technic will vary in accordance with the symptoms and the distribution of the eruption. Localized eruptions even when acute, will often undergo complete involution subsequent to from three to six weekly (75 r, unfiltered) applications.

Widespread eruptions must be cautiously irradiated. These patients are already somewhat toxic and their skin is very sensitive. It is advisable, therefore to employ very small doses and to expose only one small part of the body daily. Complete technical details for such

treatment will be found in Chapter VIII under the heading of Generalized Roentgenization (p. 312).

DERMATOPHYTOSIS.

The term dermatophytosis, for convenience, may include any eruption of eczematoid appearance that is caused by fungi, and dermatophytid may include all eruptions caused by sensitization to fungus products. Hence is included in this group: eczema intertrigo of the toes and fingers (eczematoid ringworm of the extremities), eczema marginatum, eczematoid ringworm of the body, eczematoid eruptions of the pubic region, umbilicus, axillæ and under pendulous breasts when due to fungi, moniliasis, erosio interdigitalis blastomycetica, perlèche, erythrasma, and patches of eczema on any part of the body caused by fungi or their products.

The member of this group that is of particular interest is the condition (eczematoid ringworm of the extremities) described by Djelaleddin-Mouktar in 1892, by Whitfield and Sabouraud in 1910 and by Ormsby and Mitchell in 1916. Modern terms are dermatophytosis and "athlete's foot." The disease is limited to the hands and feet and occurs in three clinical varieties: (1) Acute vesicular or vesicopustular, clinically identical with acute vesicular eczema and pompholyx It attacks mostly the fingers, toes, palms, and soles. (2) Chronic intertriginous, commonly seen between the toes, occasionally between the fingers. (3) Hyperkeratotic, clinically identical with chronic squamous eczema and occurring on the soles, also on the palms.

First Type.—As a rule the best treatment for this type of dermatophytosis is some antiparasitic and antipruritic topical remedy such as Whitfield's ointment, tr iodine, chrysarobin, wet dressings in very severe acute cases, etc. However, some cases do not do very well under this treatment and it is in such cases that irradiation is of value. In many instances, especially eruptions on the hands, the lesions will disappear apparently as a result of three or four weekly doses (75 r), combined with soothing local remedies such as Lassar's paste and calamine lotion, both of which may contain menthol, camphor and carbolic acid. Recurrence is common. Even stubborn or relapsing cases may at times remain cured following irradiation. It must be admitted that cases are numerous in which the eruption fails to disappear One may combine irradiation with the irritating and stimulating remedies enumerated above provided they are used in very weak strength. The best plan is to avoid them when employing x-rays.

Dermatophytosis of this type, when occurring on the feet, appears to be more stubborn than when on the hands. We have seen examples of this disease resist x-ray treatment over a period of three or four months. Conversely, there have been cases that failed to get well under topical therapy that were cured as a result of six or eight x-ray treatments.

As a summary, about all that can be said at present is

1 The acute symptoms of the first type may subside in a few weeks under x ray treatment, especially when combined with local soothing and very mild antipruritic remedies

2 Occasionally the condition is permanently cured Very often, after subsidence of the acute symptoms, no further improvement is noted Recurrences are common

3 It is our opinion that the majority of cases will do better under intelligent conventional therapy than under irradiation

Second Type —There is no doubt in our minds that properly administered dermatologic treatment is superior to irradiation in this type of eczematoid ringworm Irradiation is useful in stubborn cases

Third Type —We have had better results with dermatologic remedies than with x rays in the treatment of hyperkeratotic dermatophytosis There is, of course always the question of diagnosis Certainly some cases do very well under x ray treatment

Technic —Weekly applications of 75 r unfiltered doses are advisable because

1 Inflamed tissue is hypersensitive to x-rays

2 Susceptibility may be increased by the previous use of strong topical remedies

3 It has been found that if the eruption will yield to x rays it will respond to a few small doses

If the eruption does not disappear as a result of such treatment over a period of a month or six weeks, it is unlikely to be favorably influenced by further treatment

Filtered radiation is not more efficacious than are unfiltered x rays

It is often necessary to irradiate the lateral surfaces of the fingers and toes This may be accomplished (for the fingers) by placing the palms on the table with the fingers widely separated The x-rays are administered to the dorsal surfaces of the fingers The dorsal surfaces of the hands are then placed on the table and irradiated Both hands can be treated at one time although it is preferable to irradiate each hand separately The same procedure is carried out for the toes except that the latter must be held apart by gauze plugs

If there is a single patch or only two or three isolated areas, the normal skin should be protected In the case of a widespread eruption or if there are numerous lesions, it is preferable to allow the rays to spread over the hands Such small doses will not harm the normal skin between the lesions

Dermatophytosis and dermatophytid of various parts of the body may be dry or moist sharply or poorly marginated and defined The terms parasitic eczema eczema marginatum, eczematoid ringworm moniliasis etc are often used by clinicians to designate such eruptions The term dermatophytosis suggested by Walter Highman and dermatophytid (Williams) have been used to designate the entire group While x rays and radium will often benefit and perhaps cure eruptions

of this type, better results are obtained, as a rule, by conventional dermatologic management. Variation in stubbornness may be due to the genus and species of the causative fungus. For additional information the reader is referred to Chapter XXVII.

NEURODERMATITIS.

Neurodermatitis includes or will include here lichenification, lichenified eczema, eczema nuchæ and lichen simplex (Vidal). There seem to be two very distinct types of the eruption—circumscribed and disseminated. The circumscribed variety occurs as dime to palm-sized areas. There may be one or two patches or numerous lesions scattered over the body. The sites of predilection are the nucha, the lateral surfaces of the neck and the flexures. Lesions may occur, however, on almost any part of the body particularly on the extensor surfaces near the knees and elbows.

The disseminated type (atopic dermatitis or atopic eczema) favors the flexures and flexor surfaces, but it may be quite generalized and even universal. There is usually a family history of hay fever and asthma and the patients are often sensitized to various substances.

The objective symptoms are lichenification, more or less acanthosis and parakeratosis, excoriation and, at times, exudation. The subjective symptom is itching which may be intense and which often precedes the appearance of the eruption.

Effect of Irradiation.—Most authors agree that irradiation is usually effective in the circumscribed types of neurodermatitis.

As a rule from three to six weekly treatments will suffice for a clinical cure. Occasionally the lesions are more stubborn and require treatment over a period of two or three months. Not infrequently an eruption will not improve, or at least will not entirely disappear, without an amount of radiation that is undesirable. It is preferable to avoid reactions and if the eruption does not disappear as a result of treatment over a period of two months, it is advisable to discontinue irradiation. Itching usually disappears before the eruption shows signs of involution. Recurrences are common. When the eruption involves the scalp the dose should be about 38 r instead of the usual 75 r and limited to four treatments at weekly intervals. A second course may be given a month later if necessary. When the eruption recurs several times some treatment other than irradiation should be used regardless of location. Grenz rays are at times useful for this type of neurodermatitis, especially when involving hairy parts.

There seems to be little if any difference in efficacy between the beta and gamma rays of radium, between radium and *x*-rays, or between filtered and unfiltered *x*-rays. When using radium it is customary to utilize a half-strength flat applicator screened with 0.1 mm. aluminum. It is placed in contact with the skin for about five minutes each week. The normal skin around the lesions should be protected and strong

Fig 173 —Circumscribed neurodermatitis before treatment

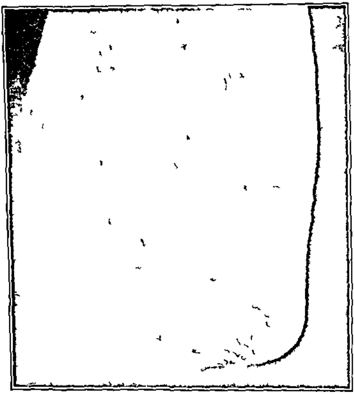

Fig 174 —Same patient shown in Fig 173 after six fractional treatments (75 r unfiltered weekly) Scar at upper part of picture is the result of a biopsy

topical applications are contraindicated. It is permissible to employ diluted carbolic acid and menthol to allay the itching while awaiting the antipruritic action of the radiation.

Disseminated Neurodermatitis.—The effect of irradiation on this type of neurodermatitis is uncertain. The treatment practically always causes some relief, but it very frequently fails to cause complete disappearance of the eruption. Even when the eruption does disappear recurrence is the rule. Nevertheless the *x*-rays are a valuable adjunct to general medical and conventional dermatologic treatment. The fact that they will lessen the itching and directly or indirectly improve the eruption in the majority of cases of this stubborn disease, is all that is necessary to justify their use. As this disease usually persists, intermittently, over a period of many years, *x*-rays are indicated, as a rule, only to help get the case under control during a severe exacerbation. The physician should guard against the accumulative effect of repeated courses of treatment by keeping adequate records. It is preferable to avoid a total of more than about 1200 r on any part of the body during the life of the patient.

Technic.—Inasmuch as it is often necessary to irradiate extensive surfaces, small weekly doses (38 to 75 r weekly to any one part of the body) are indicated. The reasons for this advice and the necessary technical details will be found in Chapter XXV. Everything possible should be done to ascertain and eliminate the causative factors. This condition frequently involves the eyelids. There have been a number of legal actions based on the production of the so-called *x*-ray cataract. Also, in recent years there has been a number of reports of cataracts in children, adolescents and adults, afflicted with neurodermatitis disseminata, to whom *x*-rays or radium had never been applied. In view of these facts and in spite of the high resistance of the eye to *x*-rays and radium, it is advisable, for medicolegal reasons, to apply very little radiation to the eyelids without adequately protecting the eyeball.

CHRONIC LICHENOID, DISCOID, EXUDATIVE DERMATOSIS.

This disease, which closely simulates disseminate neurodermatitis, was definitely separated from the latter by Rosen, Sulzberger and Garbe. It occurs mostly, if not entirely, in adult male Jews. The cause is not well understood but it is closely associated with psychogenic disturbances. The chief subjective symptom is severe pruritus. The eruption and the pruritus, often generalized or universal, do not respond well to *x*-rays although they are beneficial in some cases.

INFANTILE ECZEMA.

We are unable to recognize any variety of eczema that is peculiar to infants, therefore eczema infantilis is not an entity. With the exception of dermatitis hemostatica and neurodermatitis circumscripta

it is possible to identify in infants all the varieties of eczema that occur in children adolescents and adults, and it is important to do so because recognition of variety affords a clue to the probable cause Most dermatologists avoid the use of *x* rays for the treatment of eczema of infants and children When used for this purpose the treatment is limited to a few doses *of from 20 to 40 r, unfiltered, at weekly* intervals Small areas of eruption are at times treated with grenz rays

DERMATITIS SEBORRHEICA

Of seborrheic dermatitis or seborrheic eczema there are several clinical varieties Seborrheic dermatitis of the scalp comprises seborrhea sicca (pityriasis simplex capitis) pityriasis steatodes and oily seborrhea or it may be manifested as a squamous eruption that is quite indistinguishable from psoriasis At times the eruption is pustular, exudative and crusted

On the body the disease affects the face, the neck, ears chest, axillae, umbilicus, crural region, flexures, the spinal region, and occasionally the eruption may involve other parts and, in fact, it may become generalized The eruption may consist at one extreme of poorly outlined areas of dry or waxy scaliness without much evidence of inflammation At the other extreme there may be considerable inflammation and even exudation There is a follicular type, a circinate type and a psoriasiform type The last, at times so closely *resembles psoriasis that it is impossible to differentiate*

The above conception of the disease is broader than that held by many dermatologists It is possible that seborrheic dermatitis clinically is not inflammatory, inflammatory symptoms may occur as a complication However the conception given above will answer our purposes

Dermatitis Seborrheica Capitis —Irradiation has not seemed to be of benefit in the treatment of seborrhea sicca, pityriasis steatodes or oily seborrhea of the scalp Exudative eruptions and psoriasiform eruptions of seborrheic dermatitis on the scalp are, at times benefited In obstinate cases the *x*-rays warrant a trial

The technic employed by us consists of applying 38 r, unfiltered, to the entire scalp by the Kienbock-Adamson five exposure method once weekly for four treatments It is not considered safe to administer more than 150 r to the scalp in one month, as 225 r given in three weeks have been known to effect a defluvium The details of this technic will be found under the headings of Tinea capitis and Psoriasis

If, one month after the last exposure, the eruption has not disappeared, a second course of treatment may be given *If the eruption* has not disappeared as a result of two or three courses it is advisable to discontinue the treatment

Strong topical applications should be avoided during the x-ray treatment. Grenz rays are useful for small patches.

Dermatitis Seborrheica Corporis.—Irradiation is at times of service in cases of oily seborrhea of the face, but the treatment must be cautiously applied. The technical details, precautions to be taken, etc., are the same as given under acne vulgaris and with the exception of a few essential points will not be reiterated here. Applications of 75 r once weekly may be continued if necessary for four months. During this time the skin should be carefully inspected every week for evidence of lessened sebaceous activity. As soon as there is distinct improvement, treatment should be arrested, otherwise the skin may become harsh, scaly and dry. In obstinate cases it is not advisable to continue treatment for more than four months because a continuation of treatment may result in slight but perceptible wrinkling of the skin, especially the skin near the mouth. The sebaceous glands in different persons vary greatly in susceptibility. In some cases a few treatments will overcome the excessive oiliness. At the other extreme we have seen skin remain oily even after irradiation had been pushed to the point of visible atrophy.

Scaly seborrhea of the face and body will at times disappear as a result of a few treatments, but as a rule the condition can be more quickly cured with ordinary dermatologic remedies. However, in stubborn cases irradiation is at times of distinct value. These remarks may be applied, also, to the follicular type of the disease.

The best results may be expected in psoriasiform eruptions. While one meets with eruptions of this type that cannot be clinically cured with x-rays, the majority of cases will yield quickly, and many of them permanently, to irradiation. It must be admitted, however, that recurrence is rather common.

Because of the large number of lesions and the extent of the affected surface, and also the fact that these lesions are likely to be hypersensitive, mild treatment is indicated. It has been our experience that if seborrheic dermatitis does not disappear as a result of from three to six treatments consisting of 75 r each at weekly intervals, it will not disappear as a result of further irradiation.

INTERTRIGO.

An inflammation of the skin situated in locations where there is moisture, warmth, friction and where it is difficult to keep the parts clean, is known as intertrigo. The usual sites are the crural region, the axillæ, the anal region, and the breasts (under pendulous breasts). The eruption usually consists of redness, maceration, erosion, exudation and itching or burning. It is necessary always to differentiate the eruption from an eruption due to fungi and from seborrhea. Eczema intertrigo, or intertriginous eczema, is a term given to the eruption

when the symptoms are more like those that are visualized by the word eczema—thickening, vesiculation pustulation, exudation, etc

As a rule intertrigo will disappear in a few days or a week or two under the influence of proper hygiene and the intelligent use of topical remedies Occasionally, however the disease persists in spite of such treatment In such instances irradiation consisting of 75 r unfiltered may be beneficial The x-ray treatment should of course be combined with soothing local remedies hygiene and, later, prophylactic measures should be instituted in order to prevent recurrence

The method of applying x-rays to the crural region is discussed under the heading of pruritus to the axillæ under the heading of hyperidrosis

To irradiate the gluteal fold the patient lies on his stomach and with his hands the buttocks are separated Or the buttocks may be separated by two pieces of wide adhesive plaster the distal ends of which are attached to the table To irradiate the skin under the breasts it is necessary for the patient to elevate the breasts with the hands All unaffected parts should be shielded

REGIONAL ECZEMA

Eczema of the Scalp —Both exudative and squamous eczema of the scalp may be benefited by irradiation In fact the x-rays are a blessing in some cases as they obviate the necessity of using disagreeable salves and lotions The treatment may consist of 38 r once weekly until 150 r have been administered It is not safe to exceed this dose unless one does not mind a defluvium Strong topical remedies are contraindicated, slightly stimulating remedies are permissible Crusts and exudates should be removed with oil or with water and soap before the x rays are applied If the entire scalp is affected the x rays are administered in accordance with the Kienbock Adamson five exposure method (see tinea capitis) If more than one course of treatment is necessary a rest interval of at least three weeks between each course is advisable

Eczema of the Face —Exudative and squamous eczema of the bearded region will often disappear as a result of a few mild treatments The method of application is discussed under the heading of sycosis

Eczema of the lips, nostrils eyelids and ears will often disappear when treated either with x rays or radium For the eyelids the total dose in a month should be not more than 150 r This is also true of the lips as the mucous membranes are rather sensitive The eyes will not be injured by this amount of irradiation The consensus is that the eyeball is quite radioresistant At least the eyelids are much more radiosensitive than is the eye However, because of reports of "x ray and radium cataract and legal actions based thereon, it is preferable not to apply x rays or gamma rays to benign lesions and

eruptions of the eyelids without suitable protection for the eyes. Grenz rays and beta rays may be used in moderation.

Eczema of the Scrotum.—When irradiating the scrotum it is advisable to limit the total dosage to an amount that will not seriously injure the testicles. The testicles are extremely radiosensitive and

Fig. [illegible].—Acute vesicular eczema before treatment.

prolonged treatment will effect azoospermia. Four to six weekly treatments 75 r unfiltered, will often suffice to cure the eczema and this amount, in our experience, is not enough to do more than diminish, temporarily, the activity of the seminiferous tubules. It is not advisable to push the treatment beyond this point. It is possible to push the testicles into the inguinal canal where they may be held by the

patient, whose hands are protected with lead-rubber or lead foil Even with such protection it is possible for the testes to be injured by scattered radiation If additional roentgen therapy is necessary the semen should be examined every few weeks When treating recalcitrant cases there will be less injury to the testicles with "soft beta rays of radium

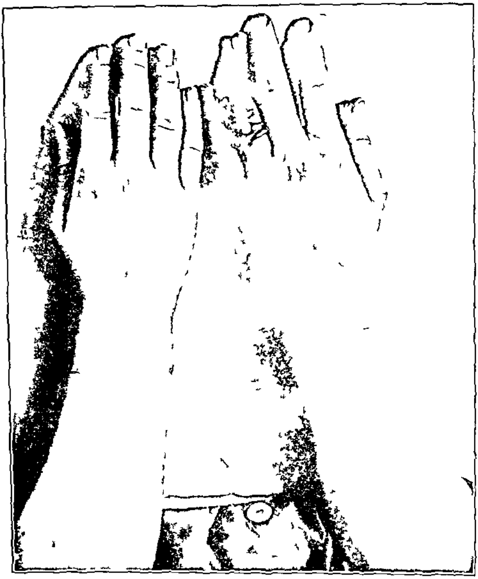

Fig 176 —Same patient shown in Fig 175 after three fractional doses of x ray

than with gamma rays or x-rays A half-strength applicator screened with a layer of oiled silk may be left in contact with the skin for one or two minutes once weekly Chronic lichenified eczema of the scrotum may require treatment directed at both the anterior and posterior surfaces A month or two of such treatment (x rays) may jeopardize the testicles An unscreened flat radium applicator would seem pref

erable in such instances. The "soft" beta rays act so quickly that the amount of gamma and "hard" beta rays received by the testicles would be almost negligible Of course, there is a limit to such treatment, but just what constitutes this limit we do not know. This question is discussed in greater detail under the heading of pruritus. Conservative doses of grenz rays would seem to be indicated for eczema of the scrotum.

Eczema of the Nipple and Breast of Women.—Here the first requisite is to be certain that the case is not one of Paget's disease. If eczema of the nipple and breast (omitting the possibility of Paget's disease) does not disappear as a result of one or two months' irradiation, it is inadvisable to continue the treatment for fear of injury to the underlying glands In obstinate cases "soft" beta rays, or grenz rays, might be used to advantage.

Eczema of the Legs.—Ordinary eczema of the legs does not differ from that of other parts, but in this location there are special features to be considered. Here one meets with an eczematized skin associated with deep edema, the latter being due to varicose veins or cardiovascular disturbances, and the former very largely to scratching. There may be more or less purpura (dermatitis hemostatica, Klotz). This variety does not respond well to irradiation unless attention is paid to the underlying causative factors. If this is done, *x*-rays will be of benefit by allaying the itching and promoting resolution of the thickened skin. They are of service, also, in hastening healing of exudative areas and ulcerations. Very often all the surfaces of the legs are involved necessitating multiple exposures (see Chapter on General Therapeutic Considerations).

Eczema of the Hands and Feet.—Eczema of the hands and feet is often dermatophytosis, dermatophytid or dermatitis venenata. These have been discussed in this chapter.

Of special interest is the hyperkeratotic (parakeratotic) and fissured eczema of the palms and soles of obscure or unknown etiology. Often this type of eczema will disappear as a result of three or four weekly treatments Some cases are very refractory, some will not improve and recurrences are common. If the eruption does not respond to a reasonable amount of treatment, irradiation should be discontinued, for a continuation of such treatment may injure the coil and sebaceous glands, leaving the skin rough and dry, without curing the eczema

It is often necessary to irradiate the entire palmar surface of the hands and fingers, or the plantar surfaces of the feet and toes. For technical details of the method of application of *x*-rays to surfaces of this kind the reader is referred to the chapter dealing with hyperidrosis

One frequently hears the term nummular eczema. This consists of marginated patches of eczema with a predilection for the dorsal surfaces of hands and wrists It has not yet been declared a definite entity nor a definite variety of eczema. The cause has not been determined. It is likely to be stubborn. It yields fairly well to *x*-ray

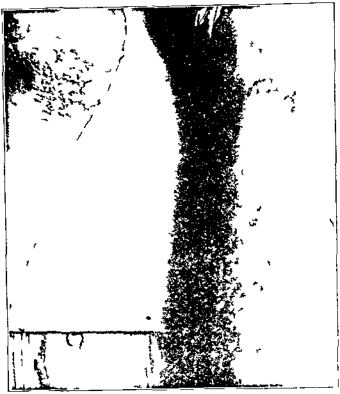

Fig 177 —Vesiculo squamous eczema before x ray treatment

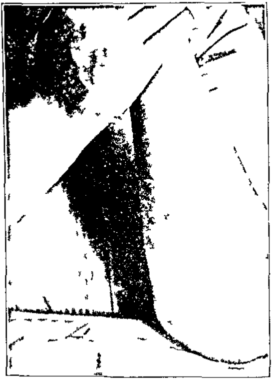

Fig 178 —Same patient shown in Fig 177 after four weekly applications of 75 r each

treatment However, if 75 r unfiltered once weekly for six weeks is ineffective, additional irradiation is likely to prove useless.

General Considerations and Summary.

We have now considered the effect of irradiation on the various clinical entities belonging to the eczema group and also certain regional types of the disease. It remains to discuss briefly the effect of irradiation on eruptive types of the disease—acute and chronic, localized and generalized eczema of uncertain or unknown etiology.

Eczema Erythematosum.—Irradiation has not given good results in acute erythematous and edematous eczema If there is not much edema and the subjective symptom is itching rather than stinging or burning, a few very mild (38 r) applications may be beneficial.

As a general proposition, both in localized and generalized acute erythematous eczema, irradiation is contraindicated in the early stage of evolution If the eruption persists, and becomes pruritic, exudative, acanthotic or squamous, *x*-rays are indicated and may accomplish considerable good

Eczema Vesiculosum, Pustulosum and Exudativum.—Exudative eczema may begin as an acute erythematous and edematous, vesicular or pustular eruption, or it may evolve subacutely or it may constitute an exacerbation occurring in a chronic eczema Eruptions of this kind, especially when restricted in extent, often disappear more quickly under the influence of *x*-rays than with any other method of treatment. The results are at times spectacular and permanent The outcome will depend partly upon the technic but largely upon the cause If the etiologic factors continue to operate the eruption is likely to be uninfluenced or only slightly influenced by roentgenization. These statements apply also to follicular and papular eczema.

Eczema Squamosum.—The chronic types of eczema associated with parakeratosis and acanthosis will disappear quickly as a rule under the influence of *x*-rays or radium The rapidity and permanence of the cure will depend largely upon the underlying causes

Value of Irradiation in Eczema—Considered as one of many remedies used in the treatment of eczema, omitting types of eczema for which there are specific remedies, and visualizing the disease in a very general way, it is our opinion that *x*-rays are of great value in the treatment of eczema In a general way it is our best antipruritic and our best resolvent agent for this purpose However, too much must not be expected It is absolutely essential that everything possible be done to determine and eliminate the external and internal causative factors. Also, the patient should receive the benefit of regular dermatologic treatment, intelligently administered, care being taken not to use strong tar, mercury, sulphur and other compounds when employing the *x*-rays

General Technical Suggestions —The acute types of eczema, even when localized, should receive very mild application (38 r) Widespread eruptions of any type should receive weekly applications of from 38 to 75 r When treating generalized or universal eruptions not more than about one-fourth of the body surface should be treated at one time If this suggestion is not followed the eruption may get worse, there may be cutaneous or constitutional toxic symptoms and the lymphocytic count may be lowered

In our experience filtered *x*-rays are no more efficacious than is unfiltered radiation even in eruptions that show considerable parakeratosis and acanthosis

Radium —Radium is not suitable for widespread eruptions In the case of small patches the results of radium treatment are the same as those obtained with *x*-rays Radium is especially indicated as already mentioned, for the treatment of eruptions situated on the scrotum and eyelids As a routine it is advisable to screen with 0 1 mm aluminum and to give about ¼ erythema dose once weekly for three or four treatments

BIBLIOGRAPHY

ALBERS-SCHONBERG Ueber die Behandlung des Lupus und des chronischen Ekzems mit Rontgenstrahlen Fortschr a d Geb d Rontgenstrahlen 2 20 1898

ALBERS-SCHONBERG and HAHN R Die Therapie des Lupus und der Hautkrankheiten mittels Rontgenstrahlen Munchen med Wchnschr 47 284 325 363 1900

ALLEN C W Radiotherapy and Phototherapy Philadelphia Lea & Febiger 1904 p 280

DJELALEDDIN MOUKTAR Quoted by Sabouraud R Eczematoid Ringworm of the Extremities and Groin Brit Jour Dermat 23 384 1911

DJELALEDDIN MOUKTAR Quoted by Whitfield A Eczematoid Ringworm of the Extremities and Groin Brit Jour Dermat 23 375 1911

ENGMAN M F Quoted by Schamberg J F Remarks Upon the Microbacillus of Seborrhea (Sabouraud)—Preliminary Report Upon an Examination of the Sebaceous Glands of the Nose Jour Cutan Dis and Genito Urin Dis 20 99 1902

FORDYCE J A Infectious Eczematoid Dermatitis Possible Influence of Anaphylaxis in Skin Reactions Jour Cutan Dis 29 129 1911

FREUND L and SCHIFF E Weitere Anwendungsgebiete der Radiotherapie Fortschr a d Geb d Rontgenstrahlen 3 109 1900

HAHN R Die Rontgentherapie bei Ekzem Psoriasis Rosacea Acne vulgaris and Prurigo Fortschr a d Geb d Rontgenstrahlen 5 39 1901

HYDE J N MONTGOMERY F H and ORMSBY O S A Contribution to the Subject of Radiotherapy and Phototherapy in Carcinoma Tuberculosis and Other Diseases of the Skin Jour Am Med Assn 40 1 1903

JUTASSY Mit Rontgenstrahlen behandelte Falle von Lupus vulgaris Ekzema chronicum Nævus vasculosus und Hypertrichosis mit Vorfuhrung der Kranken Fortschr a d Geb d Rontgenstrahlen 3 118 1900

MACKEY E Eczema Treated by Roentgen Rays 2 Cases Brit Jour Dermat 11 160 1899

MEEK E R A Variety of Skin Lesions Treated by X ray Boston Med and Surg Jour 147 152 1902

ORMSBY O S and MITCHELL J H Ringworm of the Hands and Feet Jour Am Med Assn 67 711 1916

POLLITZER S A Recurrent Eczematoid Affection of the Hands Jour Cutan Dis 30 716 1912

PUSEY W A and CALDWELL E W The Practical Application of the Rontgen Ray in Therapeutics and Diagnosis Ed 2 Philadelphia W B Saunders Company 1904 p 382

RASCH, C. Quoted by Fox, G H A Case of Match-box Dermatitis, Jour Cutan Dis, 36, 530, 1918
ROBINSON, W D [Eczema of the Forehead and Elbow Treated by X-ray], Case, Med News, 82, 190, 1903
SABOURAUD R Eczematoid Ringworm of the Extremities and Groin, Brit. Jour Dermat, 23, 384, 1911.
SCHOLTZ, W · Ueber den Einfluss der Röntgenstrahlen auf die Haut in gesunden und kranken Zustande, Arch f Dermat u Syph, 59, 421, 1902
SJÖGREN, T and SEDERHOLM, E Beitrag zur therapeutischen Verwertung der Röntgenstrahlen Fortschr a d Geb d Röntgenstrahlen, 4, 145, 1900-1901
SULZBERGER, M B, and GARBE, W Nine Cases of a Distinctive Exudative Discoid and Lichenoid Chronic Dermatosis, Arch Dermat and Syph, 36, 247, 1937.
ULLMANN, C · Der Einfluss des Lichtes auf die gesunde und kranke Haut, Wien. med Presse, 41, 897, 954, 1900
WHITFIELD, A Eczematoid Ringworm of the Extremities and Groin, Brit Jour Dermat, 23, 373 1911
WILLIAMS, F H The Roentgen-rays in Medicine and Surgery, 2d ed, New York, The Macmillan Company, 1903, p 408
ZEISLER, J Radiotherapeutic Observations, Jour Am Med Assn, 40, 511, 1903

CHAPTER XXIX

PSORIASIS PARAPSORIASIS DERMATITIS EXFOLIATIVA

THESE three diseases are considered in a single chapter because dermatitis exfoliativa may occur as a complication of psoriasis parapsoriasis is included simply on account of its name

PSORIASIS

Strater seems to have been the first to treat psoriasis with *x* rays (1900) Hahn Albers-Schonberg Startin and others reported cases at about the same time In this country the first reports of the roentgen-ray treatment of psoriasis were made by F H Williams, Pusey, Allen, and Zeisler Holzknecht, Blaschko and Wickham and Degrais were the first to employ radium for this purpose

There is hardly a dermatologist who has not written or spoken at medical society meetings of the use of *x*-rays or radium in the treatment of psoriasis Consequently the literature dealing with the subject is voluminous

Clinical Types —Psoriasis may begin as a generalized eruption of discrete rapidly evolving lentil sized or split-pea-sized red conical, scaly papules This is psoriasis guttata It is the acute type, but the symptoms as a rule are not those of an acute inflammation

The eruption may undergo spontaneous involution in a few weeks or months but it is more likely to persist and evolve into the nummular, inveterate or other chronic types The disease may begin insidiously, a few lesions occurring at the sites of predilection—knees, elbows extensor surfaces of the extremities, scalp, etc These lesions increase slowly in size and numerically until perhaps large surfaces are involved

Between these two extremes there are various clinical types hence the terms psoriasis punctata, guttata, nummularis, gyrata, geographica, inveterata, discoidea annulata, rupioides ostracea, pustulosa etc The adjectives are used to denote the appearance of the eruption and to indicate rapidity of development

It is not quite correct to say that the extremes are psoriasis punctata and psoriasis inveterata At times, especially on the extremities, the disease is associated with a great deal of acute inflammation At times also the eruption becomes universal and it may then assume characteristics that compel a diagnosis of dermatitis exfoliativa These unusual examples may occur spontaneously or they may be the result of improper treatment, either medicinal or by irradiation

Before attempting to treat psoriasis with x-rays or radium the reader is urged to study the disease in some standard treatise on dermatology. The roentgenologist should know how the disease may behave when left alone and how it may act under the influence of various kinds of treatment.

Value of Irradiation.—It is doubtful if any therapeutic agent or combination of agents can compare with x-rays (intelligently employed) in general efficacy for the treatment of the lesions of psoriasis, provided the case is one that is suited for x-ray treatment. Ammoniated mercury, salicylic acid, sulphur, tar, chrysarobin and pyrogallic acid combinations, if properly employed, will often cause rapid involution of the lesions. These remedies, however, often fail largely because of the difficulty of obtaining necessary coöperation on the part of the patient. At times the failure is not due to lack of care and perseverance, it may be caused by the impotency of the drugs in some cases and idiosyncrasy of individual patients in others. Furthermore, many patients object very strenuously to the use of such disagreeable drugs as chrysarobin and pyrogallic acid.

Often isolated, small, long-standing lesions will disappear as a result of a single (150 or 200 r) dose of x-rays. Large inveterate lesions and generalized eruptions of almost all clinical types will usually undergo involution as a result of from three to eight weekly (75 r) treatments. We prefer and advise weekly treatment in all cases that are to receive x-ray treatment.

In spite of the excellent results obtained with x-rays in the treatment of psoriasis, irradiation is by no means the method of election. Extreme caution and judgment in the use of the x-rays and in the selection of cases for such treatment are necessary, not only in order to obtain good results but in order to avoid bad results.

Psoriasis is a peculiar disease. It is incurable. In some persons it is impossible to control the eruption for months at a time, new lesions developing as fast as old ones disappear. In such instances the disease may become universal in spite of the most intelligent efforts. Fortunately such occurrence is rather uncommon. After the disappearance of a psoriatic eruption there may be a long period of latency, months or even years, during which time there may be complete freedom from the disease. More commonly, occasional lesions appear which respond readily to treatment. Not infrequently the patient has repeated attacks, each of which disappears promptly when irradiated. These outbreaks may occur at frequent intervals or they may be separated by years.

Irradiation is not always successful. Rarely, an eruption fails to improve under irradiation, even an eruption that has never been previously irradiated. It is not uncommon to see an eruption improve and then fail to disappear under the treatment. New lesions will, in such cases, develop in areas that are being irradiated. Again, when recurrent outbreaks are irradiated the disease may, after several

FIG 179 — Annular gyrate and nummular psoriasis before treatment

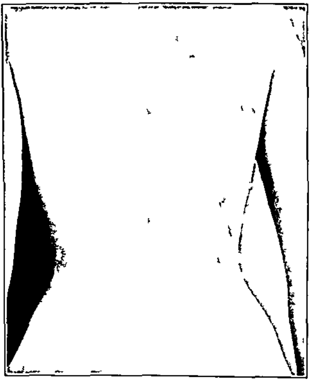

FIG 180 —Same patient shown in Fig 179 after weekly x ray treatment The temporary tanning is due to the disease

such attacks, fail to be influenced by further irradiation All these facts are of the utmost importance and should be borne in mind.

Sensitiveness of Lesions.—Psoriatic lesions are usually fairly sensitive to x-rays and radium Not only do they disappear quickly under the influence of small doses, but they react more readily to such treatment than does the normal skin. A suberythema dose may produce a first- or even mild second-degree reaction in the lesion, while the surrounding skin will not react to the same quantity. This difference in susceptibility is caused, presumably, by the amount of blood in the lesion and, also, because psoriatic lesions are so often treated with chemicals (chrysarobin, etc) which make the tissues more sensitive (see Chapter on Idiosyncrasy) For these reasons it is advisable always to employ small doses, especially when treating patients who have been using chrysarobin, pyrogallic acid, salicylic acid, mercury, etc Furthermore, such topical remedies are contraindicated while the patient is under x-ray or radium treatment.

Treatment of the Thymus.—Brock, Otto and Harry Foerster, Muhlmann, Gawalowski, Guarini, Schneider and others have treated the region of the thymus in cases of psoriasis. The Foerster brothers observed results that were encouraging. Their article is conservative and they give a complete review of the literature Gawalowski obtained 14 clinical cures in a series of 82 cases; 40 improved, 5 were unaffected, 2 got worse and 21 patients were not followed. Brock treated a large number of cases with but 2 cures and a few improvements Guarini favors the treatment Muhlmann and Schneider failed to obtain good results.

This is deep therapy, and filtered radiation should be employed. If the dermatologist attempts the work he may use 100 kilovolts, preferably 125 kilovolts at a distance of 10 or 12 inches, and a filter of 3 mm aluminum An area about 4 inches square over the thymus region, back and front, may receive a dose of 137 r once weekly. If radium is preferred, a tube containing 25 or 50 mg. of element or a corresponding amount of radon, should be screened with 1 mm. brass, 0.5 mm. silver and 3 mm. rubber At a distance of 1 inch the weekly exposure may be from fifteen to thirty minutes for each square inch of surface

In the United States, most dermatologists have abandoned this method of treatment.

Recalcitrant Eruptions—If the lesions of psoriasis will yield to irradiation they will nearly always disappear under the influence of from three to eight weekly treatments of 75 r unfiltered. If the lesions do not yield to this amount of irradiation they will not, as a rule, be benefited by further treatment, therefore a continuation of treatment beyond this point is inadvisable Long-continued irradiation of refractory lesions may be followed by a peculiar resistance on the part of the disease to any form of treatment. We are not certain that this peculiar stubbornness is the result of roentgenization That it is

occasionally encountered subsequent to roentgenization does not constitute proof because equally rebellious examples of the disease are encountered in which the lesions have never been treated with *x*-rays or radium However, the main point to be emphasized is that no good can be accomplished by a *continuation of treatment beyond the* point mentioned above

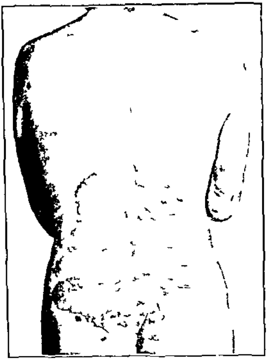

Fig 181 —Inveterate psoriasis before treatment

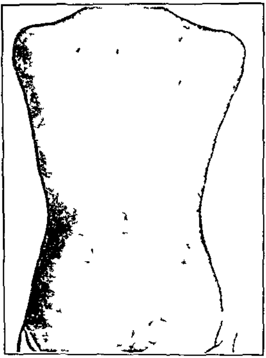

Fig 182 —Same patient shown in Fig 181 after fractional *x* ray treatment The tanning which is temporary is due to the disease

We have seen atrophy, persistent scaliness and permanent, excessive dryness of the palms and soles caused by the too persistent irradiation *of stubborn psoriasis of these regions In other words the result* of the treatment was an uncomfortable and incurable condition of the skin, a condition much worse than the disease for which the treatment was given

At times when psoriasis fails to respond normally to irradiation it will do so after a series of whole blood injections

Recurrent Eruptions —Good judgment is required in using *x* rays and radium for the treatment of recurrent attacks of psoriasis This pertains to both circumscribed and generalized eruptions Assuming that the eruption disappears as is often the case as a result of a few weekly treatments it is permissible to treat recurrences in the same manner so long as the lesions continue to respond favorably to a few small doses and the recurrences are many months apart, or the new lesions develop in locations that have not been irradiated at all It

should be recalled that five or six months of such treatment, providing the treatment is continuous, may in some persons result in atrophy of the sudoriferous and sebaceous glands. Therefore, if the relapses occur in rapid succession, so that there is no opportunity to allow a rest interval of several months between courses of treatment, it is necessary to watch the skin carefully for evidence of lessened activity of the appendages

FIG 183 —Psoriasis universalis or dermatitis exfoliativa before treatment

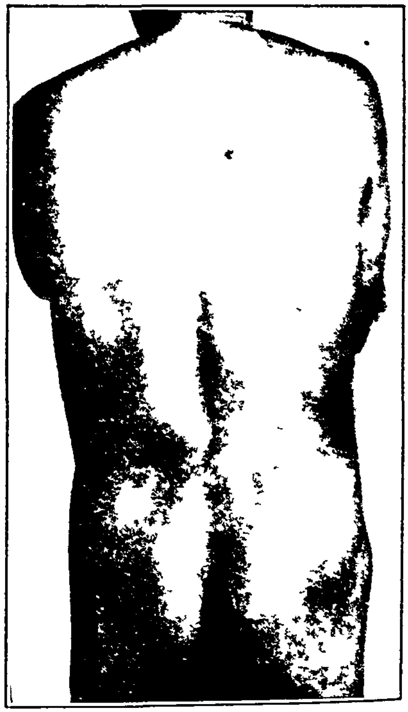

FIG 184 —Same patient shown in Fig 183 after general body roentgenization

As a matter of fact, it will be usually found that in cases exhibiting a tendency to prompt and frequent relapses, the eruption will cease to be benefited by continued irradiation.

Generalized Eruptions.—Generalized eruptions must be treated with caution If the dose is too large, or if too extensive areas are exposed at one time, the result may be systemic toxemia, toxic rashes, or the psoriasis may assume troublesome and even serious characteristics In some persons psoriasis, even when untreated or when treated with chrysarobin or other topical remedies, may acquire unusual and alarming qualities One must not, therefore, thoughtlessly blame the treatment for complications of this kind. However, the fact that psoriasis can be made worse and that local and general toxic symptoms may be produced by injudicious treatment, demands caution and judgment These statements apply not only to *x*-rays and radium, but to other forms of treatment and to combined treatment For technical

details relative to generalized roentgenization the reader is referred to the Chapter on General Therapeutic Considerations

Dosage —We prefer small doses for psoriasis In treating generalized eruptions the dose is 38 r to 75 r unfiltered, depending upon the age of the patient, the extent of the involved surface and the character of the eruption (acute or chronic in type) Circumscribed areas are treated with 75 r doses regardless of the clinical type Long experience has demonstrated that small doses give better results in psoriasis than do large doses except when dealing with a few small lesions Reasons for this preference have been given above

Erythema doses *i e* a quantity sufficient to evoke a first-degree reaction will, as a rule effect a better temporary result than will smaller doses These large doses however may produce telangiectasia Such treatment is never advisable

When treating small lesions it is advisable to shield the normal skin When treating large surfaces it is not necessary to protect the normal skin The doses used in this disease are or should be too small to injure unaffected skin

Routine Treatment —Small lesions if not acutely inflamed, should be treated with weekly doses of 75 r Circumscribed areas are treated in the same manner Generalized and universal eruptions receive half this amount

If the eruption does not undergo involution as a result of a few weekly treatments if new lesions are constantly developing or if fresh outbreaks continue to occur it is inadvisable to continue *x* ray treatment

Inflamed areas are not irradiated until the acute symptoms have subsided The use of chrysarobin pyrogallic acid tar mercury, sulphur, salicylic acid etc, is not permitted during nor for a week or two previous or subsequent to irradiation

Practically irradiation is of service in cases that resist other methods of treatment for patients who have only occasional lesions or occasional attacks and for patients who prefer to escape using disagreeable ointments

At a meeting of the New York Dermatological Society for December 1920 there was an excellent discussion relative to the value of roentgenization in the treatment of psoriasis The gist of the discussion was that in a recurrent disease like psoriasis *x* rays should not be employed as a routine but only by one who knows the disease and its characteristics and also one who is both an expert roentgenologist and dermatologist It was admitted that when properly employed and used in selected cases, roentgenization was a safe efficacious and clean method of obtaining relief from disagreeable objective symptoms and in gaining control of the disease A good point was mentioned by Winfield who warned against allowing the patient to select the treatment A patient might obtain a good result with *x* rays and then insist upon having every

...nt attack treated in the same manner, even going, perhaps, ...nt or unscrupulous physicians for the purpose. Or the patient ... having had previous x-ray treatment. Arsenical treat... offers an analogy. Patients are given arsenic for an attack of ... Every time a lesion develops they take arsenic without ... consulting a physician. Many such patients develop arsenical ...

Pustular Psoriasis.—Pustular psoriasis, most frequently affecting ... fingers, toes, palms and soles, but at times seen also on the trunk, ... and legs, is relatively insensitive to roentgen therapy. In fact, ... large proportion of such eruptions seem to be completely resistant ... radiation therapy. Six or eight weekly treatments may be tried. Our results have been poor with any safe amount of x-rays.

Another variety of eruption (of rare occurrence) is one in which the lesions assume a gray, asbestos-like, infiltrated, rough-surfaced and granular character, appearing more often on the lower extremities in the vicinity of the ankle-joints. Eruptions of this variety are as a rule radioresistant to such a degree that x-ray therapy is not advocated. Asbestos-like psoriasis is frequently unresponsive to most of the commonly employed topical remedies, of which chrysarobin compounds are by far the best.

REGIONAL PSORIASIS.

Psoriasis of the Scalp.—Excellent results may be obtained with x-rays in obstinate psoriasis of the scalp, especially when the entire scalp is involved. The manner of application consists of the Kienböck-Adamson five-exposure method, the details of which will be found under the heading of Tinea Capitis. The dose must not exceed 150 r in one month. This amount may be applied at one sitting or one may give 38 r twice weekly for two weeks, or weekly for a month. One course of treatment usually suffices; if not, a second course may be given after a rest interval of one month. The dose of 150 r should not be exceeded as 225 r has been known to effect a defluvium of scalp hair in a female blonde with psoriasis of the scalp. If two or three courses of treatment do not effect involution of the eruption it is advisable to discontinue the treatment. Infraroentgen (grenz) rays will at times give good results in this location.

Psoriasis of the Face.—For technical details relative to the application of x-rays to the face and neck the reader is referred to the chapter on Acne Vulgaris and Sycosis. If there are lesions in the eyebrows, these parts may receive as much as 150 r in a month, without danger of the hair falling out. Very "soft" x-rays (grenz) may prove advantageous for the treatment of psoriasis of the eyelids and eyebrows. When applying x-rays or radium to the eyelids it is advisable to shield the eyeball, particularly for legal reasons.

Psoriasis of the Hands and Feet —It is often necessary to expose the dorsal and palmar surfaces of the hands, and the dorsal and plantar surfaces of the feet It is possible to treat both palms or both dorsal surfaces of the hands at the same time The same is true regarding the plantar and dorsal surfaces of the feet This method does not provide uniform dosage over such large areas, but in the case of psoriasis uniform dosage is not necessary (for technical details, see hyperidrosis)

Psoriasis of the Nails —Irradiation yields fairly good results in psoriasis of the nails Lesions of the nails are more stubborn than are those of the skin It usually requires from six to a dozen or more weekly treatments to effect the desired result The skin around the nails should be shielded For further technical details the reader is referred to onychomycosis

Psoriasis of the Scrotum —Psoriatic lesions usually disappear so promptly when irradiated that in ordinary cases there is no danger to the testicles Lesions of the scrotum do not require more than three or four weekly doses, as a rule, and this amount is not sufficient to injure the testicles permanently However, possible injury to these organs must be kept in mind It is advisable not to apply more than three or four doses (75 r) and the course should not be repeated It is often necessary to expose the entire scrotum This requires a dose to both the anterior and the posterior surfaces Under such treatment the testes if not properly protected would receive a double exposure In all cases the testicles should be pushed into the external inguinal ring, and held there by the patient whose hands are covered with lead-rubber or lead foil Even when the testes are protected in this manner they may be injured by scattered and secondary radiations When more than a few weekly treatments are given it is a good plan to examine the semen

It is, generally speaking, inadvisable to treat the scrotum with x rays especially in men under fifty-five or sixty years of age We observed the case of a young man who had received minimal doses of x ray to the scrotum for an eczema The testes were retracted and covered with lead foil The patient subsequently married and was found to be sterile He attributed his sterility to the x-ray exposures Investigation revealed that he had azoospermia long before x-ray treatment was applied to his skin Unpleasant legal procedures were nipped in the bud by this revelation

Grenz-ray therapy for scrotal psoriasis is generally accepted to be a relatively safe procedure Nevertheless the same careful precautions —retraction of the testes minimal dosages adequate protection etc, must be rigidly observed with the super-soft ray therapy as with conventional methods

An unscreened flat radium applicator offers certain advantages when treating psoriasis of the scrotum The "soft" beta rays act

very superficially and also very rapidly. The exposure is so short that the dose of gamma rays received by the testes is exceedingly small. A half-strength, glazed applicator, covered with a layer of rubber tissue or oiled silk, may be held in contact with the affected areas for one or two minutes once weekly.

Leukoderma Psoriaticum.—Rarely, after the involution of psoriatic lesions, the area of the skin, previously the site of the lesion, is whiter than is the normal skin of the patient. Around this white area there is an areola which is darker than the normal skin. The dark area accentuates the white area. The condition is permanent, or at least it lasts for a long time Irradiation should not be blamed for this peculiar sequela.

Psoriatic patients often take arsenic for long periods of time. Occasionally one encounters arsenical keratoses and arsenical pigmentation, for which *x*-rays should not be blamed.

Filtration.—We have experimented with filtered *x*-rays in the treatment of psoriatic lesions of all types. The results were exactly the same as those obtained with unfiltered radiation.

Radium.—Radium is not suitable for widespread psoriasis. Small lesions disappear quickly, as a rule, when treated with beta rays or gamma rays. As far as can be determined, both *x*-rays and radium are equally efficacious. When treating lesions having a thick horny layer the "soft" beta rays should be eliminated by suitable screening. If the scales are first removed an unscreened applicator may be used, although it is advisable, as a rule, to use a thin screen, say 0.1 mm. of aluminum, in all cases, excepting when treating lesions situated on the scrotum or eyelids A half-strength, flat, glazed applicator, screened with 0 1 mm. aluminum, may be placed in contact with the lesion for about five minutes once weekly.

In a general way the discussion of the *x*-ray treatment of psoriasis will answer for radium when used for the same purpose. This includes, also, the question of dosage. An attempt should be made to avoid reactions and it is well to remember that because of the color of the lesion a mild reaction may be overlooked.

Paravertebral Roentgen Therapy.—A number of dermatologists and roentgenologists have published good results, achieved in cases of more or less generalized psoriasis by applying filtered *x*-rays to the vertebral column and to the region of the thymus. The idea is to affect the sympathetic nervous system. Most of this work was done before 1930. Very little is heard of the method now.

DERMATITIS EXFOLIATIVA.

Two clinical types are described under this title: (1) primary and (2) secondary. The primary type is called the Wilson-Brocq variety, the cause of which has not been determined. The secondary variety sometimes results from the application of external remedies, such as chrysarobin and mercury ointments, in hypersusceptible patients.

The same clinical appearance also may result from the ingestion of quinine, arsenic and other drugs and from antitoxin injections. One of the most common precursors of secondary dermatitis exfoliativa is widespread psoriasis which may become so extensive as to involve the entire body. Such a universal cutaneous inflammation sometimes follows the application of an irritant topical remedy, such as chrysarobin, at other times, the generalized eruption of psoriasis changes into a universal exfoliating dermatitis without the intervention of either external or internal sensitizing substances. A third variety included under dermatitis exfoliativa is pityriasis rubra of Hebra, a chronic universal dermatitis, associated with grave systemic symptoms and often ending fatally.

A number of years ago we treated a patient who had the primary type of dermatitis exfoliativa. The eruption was refractory, but it finally disappeared either spontaneously or as the result of several months of weekly *x*-ray treatment. A relapse occurred in a short time and further treatment had no effect. Three additional cases were treated without the slightest improvement. Two were of the secondary type, while there was some doubt relative to the third case although it, too, was probably secondary to psoriasis or eczema.

A fourth patient was successfully treated with *x*-rays for generalized psoriasis. A year later the psoriasis returned and became almost universal—secondary dermatitis exfoliativa. This eruption also disappeared as a result of irradiation. Two years later the universal eruption again appeared. X-rays had no effect. Autoserum and 1 per cent chrysarobin ointment produced a clinical cure. One year later there was another relapse, the most severe of all. This attack lasted for many months, and finally disappeared while the patient was taking large doses of quinine. Two patients with an arsphenamine eruption of the dermatitis exfoliativa type were treated with fractional *x*-ray doses and the eruption disappeared promptly.

The *x*-rays are, therefore, of uncertain value in primary and secondary types of dermatitis exfoliativa and also in the transition stage between psoriasis and exfoliative dermatitis.

PARAPSORIASIS

Parapsoriasis in its different forms is usually not amenable to *x*-ray therapy. The eruption sometimes responds—at least temporarily—to intensive ultraviolet light. However *x*-rays may be given a trial as isolated reports of favorable results are found in the literature. In such reports considerable doubt is cast on the correctness of the diagnosis. In the exudative form of the eruption—pityriasis lichenoides et varioliformis acuta—also called parapsoriasis varioliformis, the tendency toward spontaneous resolution is recognized. In severe and widespread eruptions, *x*-ray and ultraviolet therapy

have occasionally proved to be beneficial, more especially in cases tending toward chronicity.

We treated a case of generalized parapsoriasis of the lichenoid type. All lesions were given four treatments at weekly intervals, consisting of 75 r unfiltered. There was about 65 per cent improvement; after eight treatments nothing but a few papules and pigmented macules remained on the arms Ormsby tried roentgenization in a case of parapsoriasis of this type and also in a case of érythrodérmie pityriasique en plaques disseminées (parapsoriasis in plaques) without result. Wise and Rosen failed to note improvement in a case of parapsoriasis in plaques under rather prolonged irradiation. The case was one that resembled the prefungoid stage of mycosis fungoides. The fact that the eruption failed to improve under the influence of *x*-rays was used by these writers as evidence in favor of a diagnosis of parapsoriasis. Mycosis fungoides is usually amenable to *x*-ray treatment, especially in the early stages of evolution.

Maki found *x*-rays of value in the treatment of parakeratosis variegata. The original article is not available and the abstract does not give details.

Kreibich reported a case of parapsoriasis atrophicans in a young woman who, in addition to the skin disease, had amenorrhea and genital hypoplasia. She was given a dose of roentgen rays (one-sixth to one-eighth the castration dose) over the ovarian region and in response to it, menstruation reappeared and the skin disease vanished.

BIBLIOGRAPHY.

ALLEN, C W Radiotherapy and Phototherapy, Philadelphia, Lea & Febiger, 1904, p 267

BLASCHKO Quoted by WICKHAM, L, and DEGRAIS, P Radium Therapy, New York, Funk & Wagnalls Company, 1910, p 266,

BROCK, W Beziehungen der inneren Sekretion zur Schuppenflechte und deren Behandlung mit Thymusbestrahlung, Strahlentherapie, 11, 563, 1920

FOERSTER, H R, and FOERSTER, O. H A New Method of Roentgen-ray Therapy in Psoriasis, Arch Dermat and Syph, 4, 639, 1921

GAWALOWSKI, K Zvyseni funkce thymu roentgenem a jeho vliv na kuzi, Ceska dermat, 4, 94, 1923, Klinická a experimentální studie o psoriase, ibid, 5, 1, 1923

GUARINI, C Die Rontgen-Radium-Behandlung der Schuppenflechte, Dermat Wchnschr, 77, 1215, 1923

HOLZKNECHT, G Quoted by ALLEN, C. W Radiotherapy and Phototherapy, Philadelphia, Lea & Febiger, 1904, p. 534

MAKI Quoted by Mescherski' Three Interesting Cases of Parakeratosis and its Physico-therapy, Russki Joornal Kojnikh e Venericheskikh Boleznei, 29, 35, 1915, abst, Jour. Cutan Dis incl Syph, 34, 627, 1916

MÜHLMANN Ueber Roentgen-Reizbestrahlung, Verhandl d Deutsche Röntgen-Gesellsch, 14, 71, 1923, sometimes bound with Fortschr a d Geb d Rontgenstrahlen, 31, 1923

ORMSBY, O S Case Presentation of the Guttate Variety of Parapsoriasis, or so-called Pityriasis Lichenoides Chronica (Juliusberg), Jour Cutan Dis incl. Syph, 35, 44, 1917. Parapsoriasis (type érythrodérmie pityriasique en plaques disseminées), Jour Cutan Dis incl Syph, 33, 390, 1915.

POPP, W C, and ADDINGTON, E H Roentgen Therapy for Psoriasis of the Nails and Psoriatic Arthritis, Radiology, 36, 98, 1941.

PUSEY, W A, and CALDWELL, E W The Practical Application of the Rontgen Rays in Therapeutics and Diagnosis, ed, 2 Philadelphia, W B Saunders Company, 1904, p 387

ROSH RIEVA Irradiation in the Treatment of Psoriasis Am J Roentgenol and Rad Ther 32 82 1934
SCHNEIDER P Zur Thymusrontgenbestrahlung bei Psoriasis Wien klin Wchnschr 35 565 1922
STARTIN J On X rays in the Treatment of Lupus and Rodent Ulcer Lancet 2 144 1901
STRATER Welche Rolle spielen die Rohren bei der therapeutischen Anwendung der Rontgenstrahlen? Deutsch med Wchnschr 26 546 1900
WICKHAM L and DEGRAIS P Radiumtherapy London Cassell & Co 1910 p 265
WISE F and Rosen I A Case of Early Mycosis Fungoides Clinically Indistinguishable from the Parapsoriasis of Brocq Jour Cutan Dis incl Syph 34 95 1916
ZEISLER J Radiotherapeutic Observations Jour Am Med Assn 40 511 1903

CHAPTER XXX

LICHEN PLANUS.*

SCHOLTZ (1902) was the first to enter the literature with the report of a case of lichen planus treated with x-rays. Additional cases, in all of which the results were favorable, were soon reported by Zeisler, Edwards, Pusey, Gilchrist, Allen and many others.

These reports all related to the x-ray treatment of circumscribed patches of chronic lichen planus and lichen planus hypertrophicus.

Lustgarten (1904) obtained good results with x-rays in generalized lichen planus. Montgomery (1905) cured a patient who had universal and very severe lichen planus. The patient had not been entirely free of the eruption for seventeen years. The eruption had been universal for several months. It disappeared as a result of irradiation over a period of three months.

Most textbooks on dermatology and roentgenology state that the x-rays are useful in the treatment of chronic types of lichen planus. Blaschko, H. Fox, Wise, Stern and others have testified to the efficacy of the x-rays in localized and generalized lichen planus. Incidentally, Ormsby cured a case of lichen planus atrophicus with x-rays.

Wickham and Degrais seem to have been the first to report the treatment of lichen planus with radium. They cured isolated patches of chronic lichen planus in several patients. They also cured one case of zosteriform lichen planus. Simpson, Newcomet, Finzi and others recommend radium.

Types of Lichen Planus.—Lichen planus usually develops slowly and runs a chronic course. The sites of predilection are the flexor surfaces of the forearms, the inner aspect of the thighs, the glans penis and the buccal mucosa, but almost any part of the body may be involved, the eruption, in fact, may be generalized. It sometimes begins in the form of a diffuse dermatitis, devoid of papules or macules. The elementary lesion is a pinhead-sized, flat-topped, shiny, smooth, more or less polygonal, sometimes umbilicated papule. The color is lilac—violaceous. The subjective symptom is itching, which may vary from mild to intense. The papules may be discrete or they may be grouped into large patches. They may coalesce into a solid patch of lichenification—a mosaic. They may form linear, annular and gyrate configurations.

Lichen planus, treated or untreated, may last for months or years. Individual lesions may persist or the eruption may continue to exist through the formation of new lesions, the older lesions undergoing

* In the last edition, this chapter was revised by Dr. Fred Wise. Some of the material added by Dr. Wise has been retained in this edition.

spontaneous involution. It seems to be the consensus that the spontaneous cure of lichen planus is uncommon. This, however, is not our impression. While not desiring to make a definite statement, personal impression is that many cases of ordinary lichen planus will disappear without treatment in from six months to a year or two.

Individual papules of lichen planus may at times increase markedly in size or individual patches may become thickened—lichen planus hypertrophicus. Such patches may become hyperkeratotic or verrucous—lichen planus verrucosus. These types are exceedingly persistent and recalcitrant and are situated usually on the legs. They may persist almost indefinitely.

Occasionally lichen planus may develop rapidly as an acute exanthem with a generalized or almost universal distribution. In such instances the elementary lesions are so tiny and so closely crowded that they are likely to be overlooked. The color is a dull crimson; there may be slight scaliness; the subjective symptom is a very distressing combination of burning and itching.

There are other types of lichen planus, but we are concerned only with the varieties that are known to be amenable to irradiation. For further details relative to clinical types the reader is referred to standard textbooks on dermatology.

Lichen planus of the mouth and lips may simulate leukoplakia and lupus erythematosus, and, inasmuch as the technical requirements are different in the three diseases, correct diagnosis is of the utmost importance. Lichen planus is recognized by reticulation of the mucous membrane eruption and by a concomitant eruption of the skin.

Effect of Irradiation.—The result of x ray and radium treatment will depend upon the various characteristics of the eruption. Lichen planus responds in a variable and capricious manner to roentgen therapy. As a general rule, the acute and subacute varieties of eruptions, whether occurring as isolated crops or as widespread exanthems, undergo fairly prompt involution as a result of a series of weekly doses (75 r) of unfiltered radiation. On the other hand, patients whose eruptions are resistant to treatment, even when such treatment is pursued up to a "dosis tolerata," not infrequently are encountered by most dermatologists. An interesting sidelight in connection with this observation is that during the initial period of fifteen to twenty years in which irradiation therapy had been used, the general impression prevailed that the disease is in most cases readily amenable to such therapy. In the past fifteen years or so, experience has demonstrated the fact that we were too optimistic in this regard. Cases are encountered in which the eruption not only is refractory to radiation therapy, but in which fresh lesions appear during active treatment long after the stage of acute development of the eruption. This holds true also with respect to medicinal therapy. Hence one should be guarded in making prognostic pronouncements in relation to all varieties of lichen planus.

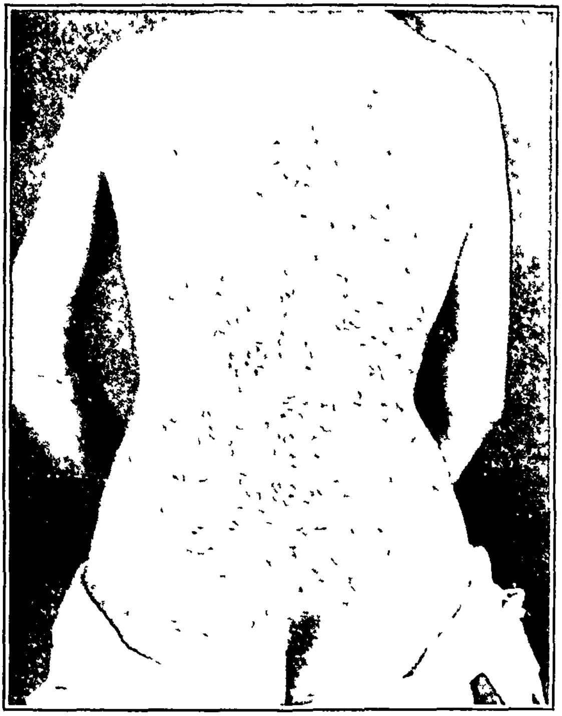

Fig 185 — Generalized lichen planus of the acute type before treatment

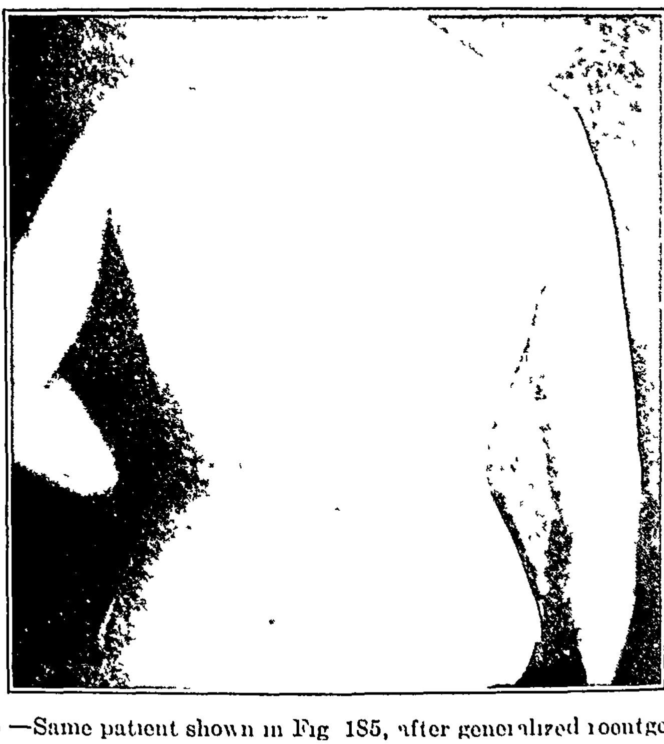

Fig 186 —Same patient shown in Fig 185, after generalized roentgenization

Acute Exanthem Type.—We have treated a number of cases of this type with x-rays. The results have been excellent. The worst and most interesting case was referred for roentgenization by John Lane, of New Haven. With the exception of the scalp and face the eruption was universal. The eruption consisted of one solid sheet of confluent tiny papules which could be seen only with a side light. The color was a dull crimson. The subjective symptoms were burning with intense itching. The eruption had been present for six months and had not improved under medicinal treatment. The very first x-ray treatment lessened the itching and burning. These symptoms improved rapidly and entirely disappeared in less than three weeks. The eruption showed evidence of involution after the first treatment. The involution was continuous. The patient was cured and discharged in seven weeks.

Another patient had a mild attack of lichen planus which disappeared in two months. One month later there was an acute universal eruption which had continued unchanged for four months when x-ray treatment was begun. The patient was cured in six weeks. Roentgenization proved very efficacious in the remaining patients.

Generalized Lichen Planus.—In the past twenty-five years over 200 patients (clinic and private) with generalized lichen planus have been treated with x rays. The eruption has varied in extent, sometimes being widely distributed over the extremities, sometimes involving the back, chest and abdomen. In the majority of cases the eruption has disappeared promptly as a result of x-ray treatment, usually in a few weeks. Many of the patients remained well. There were quite a number of relapses. A considerable proportion of patients continued to develop new lesions over a period of several months, and in several instances two years, in spite of x rays and medicinal therapy.

Localized Lichen Planus.—Localized patches of ordinary lichen planus resolve fairly rapidly when irradiated. From 4 to 8 weekly treatments usually suffice for a cure. New lesions may develop in the site of the former eruption or in new locations. This is not, however, the rule. It must not be inferred that irradiation prevents recurrence or that it exerts any influence on the unknown etiologic factor. All that can be said is that irradiation will usually cause disappearance of the lesions.

Over 300 cases of localized lichen planus have been treated with x rays. Many of these cases were of the hypertrophic type, a few were of the verrucous variety, 1 patient presented a hypertrophic lichen with lesions as large as a split walnut (Dr. Whitehouse's patient).

The results obtainable in hypertrophic lichen planus depend upon the duration of the eruption and the thickness of the tissue. From 4 to 8 weekly doses will often cause complete involution of individual hypertrophic papules and small patches of hypertrophic lichen planus. Large, thick patches are more stubborn and may require irradiation over a period of two or three months.

FIG. 187.—Annular and pigmented lichen planus before treatment.

FIG. 188.—Same patient shown in Fig. 187, after eight weekly treatments

Verrucous lichen planus is comparatively very unyielding often requiring several suberythema doses, depending of course, upon the size of the lesion and the amount of acanthosis and hyperkeratosis

Lesions of the buccal mucosa tend to be extremely refractory to most forms of therapy —both by irradiation and by medicinal remedies In some instances the skin clears in a few weeks while the buccal

Fig 189 —Lichen planus hypertrophicus before treatment The lesions on the wrists represent hypertrophic lichen planus papule The lesion on the little finger is one of verruca vulgaris

manifestations may persist for years afterward On the contrary some undergo spontaneous regression Lichen planus of the lips adjacent to the vermilion border ordinarily responds well to weekly doses of x rays In our experience lichen planus of the buccal mucosa yields well to irradiation when it is part of an acute generalized erup

Fig 190 —The same patient shown in Fig 189 after one suberythema x ray treatment The wart on the little finger was untreated but it disappeared in less than a month after the treatment of the lichen papules Tanning is due to the treatment

tion When occurring in the mouth alone or when the mouth lesions are associated with a few patches on the skin, the mucous membrane lesions are likely to resist irradiation

Irradiation vs Medicinal Therapy —It seems to be the consensus of dermatologists with which we agree that injections of arsenic mercury or bismuth and irradiation are about equally successful in a large

series of unselected cases Sonck published the following statistics: of 73 patients treated with x-rays, 42 5 per cent recovered, 35.4 per cent improved and 21.9 per cent were failures. Of 29 patients who received bismuth, 38 per cent recovered, 41.4 per cent improved and 20.7 were unchanged. Of 17 patients treated with arsphenamine, 29.4 per cent recovered, 41.2 per cent were improved and 29.4 per cent failed to improve.

Biberstein in an article soon to be published in the Archives of Dermatology and Syphilology claims satisfactory results with a vaccine.

At present, we prefer irradiation alone for localized lichen planus. For widespread eruptions we often first try conventional therapy and when this fails we institute x-ray therapy or, in many cases we employ both irradiation and medicinal therapy from the beginning.

FIG 191 —Lichen planus hypertrophicus.

FIG 192 —Same patient shown in FIG 191, after twelve weekly x-ray treatments

Sequelæ of Lichen Planus.—Lichen planus may be associated with pigmentation. At times this pigmentation may persist for several months after the eruption has disappeared Lichen planus sclerosus (lichen planus atrophicus; lichen planus morpheicus) leaves areas of atrophy, depigmentation or scars Scarring may also occur in the vesicular type of lichen planus, and pigmentation and scarring may be produced traumatically (scratching) in ordinary lichen planus. X-rays and radium should not be blamed for these sequelæ

Technic.—*Generalized and Universal Eruptions.*—The method of applying x-rays to extensive surfaces or to the entire body is described in detail in the Chapter on General Therapeutic Considerations. In acute cases the dose should be 38 r once weekly; in chronic types, 75 r once weekly.

Eruptions that are not generalized, but which occupy fairly extensive surfaces, such as the entire forearm, may be treated with weekly applications (75 r).

Circumscribed Eruptions.—Small patches of ordinary lichen planus usually respond equally well to weekly doses. These eruptions usually disappear in a month as a result of a single erythema dose, but such treatment is unnecessary and inadvisable.

We prefer weekly treatment for all types of lichen planus. In cases of verrucous lichen the thickened horny layer will permit larger doses, especially if the patches are small. It is advisable to avoid reactions, even those that might be overlooked because of the color of the lesions. When employing large doses the normal skin must be adequately protected with lead foil or other suitable material. For details relative to the application of x-rays to convex and concave surfaces and to lesions of various sizes, the reader is referred to the Chapter on General Therapeutic Considerations.

Filtration.—Filtration of roentgen radiation is of no value in the treatment of lichen planus of the ordinary types. It may be used to advantage when treating the hypertrophic or verrucous type of the disease.

Radium.—Flat applicators give satisfactory results in localized patches of lichen planus of the skin and mucous membrane. It is preferable to filter with 0.1 mm. aluminum and expose for about five minutes, once weekly. Gamma rays should be used for hypertrophic and verrucous lesions. What has been said relative to the x-ray treatment of lichen planus applies in general to the use of radium for the same purpose.

Paravertebral (Radicular) Roentgen Therapy.—Hudelo, Laporte and Kourilsky, Pautrier, Gouin and Versari, Driver, Hellier and many others have claimed excellent results in cases of lichen planus by administering x-rays to the cervical, dorsal, lumbar and sacral regions. The irradiation is limited to the spinal column and to the nerves as they emerge from the vertebral column. In case of generalized eruption, the entire vertebral column is treated. If there are lesions only on the legs the lumbar and sacral regions are irradiated. The dorsal region is exposed when the eruption is limited to the trunk and arms, and so on. The theory is that lichen planus is due to some fault in the meninges of the cord or in the nerves themselves or in the ganglia. For the most part filtered radiation has been used. However, some unfavorable results have been reported, and Hudelo *et al.* observed one case in which a localized lichen changed into an acute generalized type. Most of the authors are enthusiastic about the results. Gouin

prefers unfiltered radiation, and avers that with such radiation undesirable results are avoided. Both large and small doses have been used. It would seem most logical, if one is going to try this method, to use a filter of 3 mm. aluminum and apply about 150 r each week. Our results have not been encouraging. The method has not been used much in this country. Those who happen to be interested in this phase of the subject will find a complete bibliography on page 537 of the last (third) edition of this book.

BIBLIOGRAPHY.

Allen, C. W.: Radiotherapy and Phototherapy, Philadelphia, Lea & Febiger, 1904, p. 247.

Blaschko. Traitement des dermatoses par les rayons de Röntgen, Arch. d'electr. med., 17, 232, 1909 abst.: Treatment of Skin Diseases by X rays, Arch. Roentg. Ray, 14, 129, 1909.

Denver, J. R.: Roentgen-Ray Treatment of the Spine in Lichen Planus, Arch. Dermat and Syph., 19, 620, 1929.

Edwards, G. P.: Some Observations in X-Ray Work, Internat. Jour. Surg., 16, 299, 1903.

Finzi, N. S.: Radium Therapeutics, London, H. Frowde, 1913, p. 63.

Gawalowski, K.: De la radiothérapie indirecte du lichen plan, Bull. Soc. franç. de dermat. et syph., 34, 594, 1927.

Gilchrist, T. C.: Quoted by Allen, C. W.: Radiotherapy and Phototherapy, Philadelphia, Lea & Febiger, 1904, p. 248.

Gouin, J.: Traitement du Lichen plan par la radiothérapie du sympathique vrai (region cervicale et lombo-sacrée), Bull. méd., 38, 1015, 1924.

——— Traitement du lichen plan par le radiothérapie du sympathique (région dorsale et sacro-lombaire), Bull. Soc. franç. de dermat. et syph., 32, 80, 1925.

Gouin, J. and Bienvenue, A.: Un cas de lichen plan cutané généralisé guéri par la radiothérapie régionale axillaire. Contribution à la radiothérapie fonctionnelle sympathique cutanée, Bull. Soc. franç. de dermat. et syph., 36, 95, 1929.

——— Lichen plan et radiothérapie superficielle (nouveaux faits), Bull. Soc. franç. de dermat. et syph., 34, 356, 1927.

——— Traitement radiothérapique du lichen plan. Technique. Résultats. Mécanisme. Pathogénie, Bull. Soc. franç. de dermat. et syph., 34, 573, 1927.

Gouin, J., Bienvenue, A., and Dewing, W.: Radiothérapie sympathique dans les dermatoses. Apport de faits (150 cas). Bull. Soc. franç. de dermat. et syph. 34, 124, 1927.

Hellier, F. F.: Treatment of Lichen Planus by Exposure of the Spine to Large Doses of X-Rays, Brit. Jour. Dermat., 55, 11, 1943.

Hudelo, L., Laporte and Kotzilsky, R.: Lichen plan généralisé développé au cours d'un traitement radiothérapique radiculo-médullaire de lichen plan discret, Bull. Soc. franç. de dermat. et syph., 32, 6, 1925.

Hudelo, L., and Rabut, R.: Réflexions à propos de 108 cas de lichen observés depuis le 1er janvier 1922, Bull. Soc. franç. de dermat. et syph., 34, 540, 1927.

Lustgarten, S., in discussion on Allen, C. W.: Lichen Planus, Jour. Cutan. Dis., 22, 190, 1904.

Montgomery, F. H.: A Case of Severe Generalized Lichen Planus, Jour. Cutan. Dis., 24, 78, 1906.

Newcomet, W. S.: Radium and Radiotherapy, Philadelphia, Lea & Febiger, 1914, p. 184.

Ormsby, O. S.: Lichen Planus Atrophicus, Jour. Cutan. Dis., 28, 467, 1910.

Ormsby, O. S., and Montgomery, H.: Diseases of the Skin, 6th ed., Philadelphia, Lea & Febiger, 1943, p. 320.

Pautrier, L. M.: Note sur resultats de la ponction lombaire dans le traitement du lichen plan sur l'etat du liquide céphalo-rachidien, Bull. Soc. franç. de dermat. et syph., 34, 571, 1927.

——— Le Traitement du Lichen plan par la radiothérapie médullaire, Bull. Soc. franç. de dermat. et syph., 34, 602, 1927.

Pelizza, J.: Radiothérapie du lichen plan, Rev. d'actinol., 5, 71, 1929.

Pusey W A in discussion on White C J Lichen Planus Jour Cutan Dis 37 680 1919

Pusey W A and Caldwell E W The Practical Application of the Rontgen Rays in Therapeutics and Diagnosis 2d ed Philadelphia W B Saunders Company 1904 p 389

Scholtz W Ueber den Einfluss der Rontgenstrahlen auf die Haut in gesundem und krankem Zustande Arch f Dermat u Syph 59 87 241 421 1902

Simpson F E Radium in Skin Diseases Jour Am Med Assn 61 80 1913

Sonck C E Treatment of Lichen Ruber Planus Especially with Roentgen Irradiation and Bismuth Injections Comparative Study of the Results Finska lak sallsk handl 79 702 1936

Stern S A Report of 800 Dermatological Cases Treated with X Ray and High Frequency Currents at the Mount Sinai Hospital Jour Cutan Dis 25 459 1907

Wickham L and Degrais P Radiumtherapy Translated by S Ernest Doré London Cassell & Co 1910 p 276

Wise F Roentgen Ray Treatment of Wide Spread and Generalized Diseases of the Skin Jour Am Med Assn 73 1491 1919

Zeisler J in discussion on White C J Lichen Planus Jour Cutan Dis 37 679 1919

——— Radiotherapeutic Observations Jour Am Med Assn 40 511 1903

CHAPTER XXXI.

PRURITUS. PRURIGO

THE analgesic and antipruritic properties of *x*-rays were early recognized. The earliest textbooks called attention to these attributes of the radiation (Freund, Pusey, Williams, Belot, Allen, etc.).

For many years it was thought that *x*-rays were a powerful and useful analgesic for the relief of pain. Hence we read of the apparent benefit of such treatment in cases of zoster, sciatica, neuritis, rheumatism, neuralgia and many other diseases in which pain is a prominent symptom

Stembo reported 28 cases of neuralgia with 75 per cent of cures in three treatments Grunmach found *x*-rays useful in intercostal and facial neuralgia. Freund and Gocht report the cure of a case of severe trigeminal neuralgia of ten years' duration. Wickham and Degrais, Newcomet, Schiff and others testify to the analgesic action of radium in herpes of different types, including zoster and neuralgia. Newcomet gives C. L. Leonard the credit for being the first to recognize this action of *x*-rays on the sensory nerves

In recent years very little is heard relative to the ability of *x*-rays or radium to relieve pain by direct action on the nervous system. Theoretically, such action is possible but in practice irradiation, as a rule, seems to be of little if any value

Suffice it to say that there is very little trustworthy evidence to support the theory that *x*-rays or radium can lessen pain by direct action on nerve tissue The consensus of modern roentgenologists is that irradiation is not indicated in such diseases as zoster, neuralgia, rheumatism, etc. When relief from pain is the apparent result of irradiation it is possible that psychologic influence is the basis for the analgesic action or that recovery is spontaneous.

In such diseases as mycosis fungoides, epithelioma, sarcoma, adenitis, etc , *x*-rays and radium may lessen pain by promoting resolution of infiltration and exudation, or indirect action

PRURITUS.

That irradiation will, as a rule, arrest the itching that accompanies such diseases as eczema, lichen planus, mycosis fungoides, neurodermatitis, etc., is a well-established fact and need not be discussed here We are now dealing with pruritus that is independent of any eruption (pruritus essentialis), although lesions or an eruption may develop secondarily as a result of rubbing, scratching and strong topical remedies.

Generalized Pruritus.—Very little is known regarding the value of x-rays in the treatment of widespread essential pruritus. Oulmann reports the cure of generalized pruritus (idiopathic) of ten years' duration. The itching was most marked on the chest and back. The patient was thirty years of age. Kromayer and Howard Fox have obtained good results with x-rays in more or less generalized essential pruritus.

We have treated a large number of cases of generalized and universal pruritus and persistent itching of large areas of unknown etiology. The results have been satisfactory at times and often disappointing.

At the present moment we are of the opinion that irradiation is not indicated in widespread pruritus except when it is impossible to ascertain and remove the cause of the itching and when the distressing symptom continues in spite of regular dermatologic treatment. In such instances x-rays are likely to be of service although the relief obtained will probably be temporary.

The technic does not differ from that given under the headings of eczema and lichen planus. The dose should be small, 38 to 75 r, unfiltered, once weekly.

Regional Pruritus.—All who have had considerable experience with x-rays and radium testify to the efficacy of these agents in the treatment of persistent itching of the vulva, anal region and scrotum. As a rule, the itching will disappear entirely as a result of from three to six weekly doses of 75 r. Usually there is no relief for at least two weeks subsequent to the institution of treatment, and complete relief may not be obtained for from three to six weeks. The treatment is reasonably certain to effect at least temporary relief.

Hailey and Hailey report on the results of roentgen treatment in 105 cases of pruritus ani et vulvae. Complete relief lasting from months to years was obtained in 80 per cent and improvement in 15 per cent of the cases.

We have treated over 250 cases of regional pruritus, mostly of the anus and vulva, with x-rays. The cause could not be definitely ascertained in any of these cases. Ten patients failed to improve. Several patients required ten or more treatments at weekly intervals for complete relief. In several cases the severe itching returned in a month. In all the other patients the itching was arrested in one or two months and there was no recurrence for at least several months.

There is considerable doubt about the frequency of recurrence. In private practice many of the patients have a recurrence in from a few months to a year or two. We have a number of patients who require a course of three or four treatments every few years. In most cases each recurrence has disappeared under the influence of x-rays. In several patients the recurrences are becoming more frequent and more stubborn.

We have a record of 15 patients who did not have recurrences. Most of the patients were not seen after their first course of treatment.

The impression gained is that irradiation provides one of the most certain methods of obtaining at least temporary relief in cases of regional pruritus The relief may be permanent, but recurrences are common Everything possible should be done to locate and overcome the cause of the itching

Complications.—The usual dermatologic complications of pruritus, especially regional pruritus, are eczema, pyoderma, dermatophytosis and lichenification These complications usually disappear under the combined effects of irradiation, soothing topical remedies and cessation of scratching and rubbing

Topical Remedies.—There is no objection to the use of menthol, diluted carbolic acid, and camphor as antipruritics during the treatment, but strong preparations of oil of cade, sulphur, mercury, salicylic acid, etc , should be avoided. It is well to avoid antipruritics such as benzocaine, butesin picrate, ultracaine and similar remedies because of their high sensitizing index

Technic.—*Pruritus Ani* —The anal region is concave, and it is desirable to flatten the area as much as is possible This can be accomplished fairly well by having the patient lie on the stomach The gluteal fold may be separated by the patient with his hands. To insure against motion it is preferable to separate the gluteal fold with two strips of zinc plaster. The proximal ends of the strips are attached to the buttocks and the distal ends are fastened to the table

The lithotomy position is also suitable for this purpose, although it is less comfortable. The lithotomy position (patient on back with thighs flexed on abdomen) is the best position when it is necessary to expose the anus, the perineum and the vulva or scrotum, as is often the case.

For women it is often necessary to expose the entire region from the pubis to and including the anus In some instances this may be done by placing the target opposite the perineum In many patients it is necessary to make two exposures—one with the target opposite the upper part of the vulva and one with the target opposite the anus The radiation from the two exposures is allowed to overlap upon the perineum and lower part of the vulva. One position should be at right angles to the other.

The legs, and in fact all unaffected parts, should be adequately screened.

Filtered x-rays offer no advantage over unfiltered radiation.

Dosage.—The dose is 75 r once weekly. Full erythema doses are to be avoided on account of the possibility of telangiectasia and other sequelæ. It has been our experience that if itching cannot be arrested by administering a quantity of radiation that is insufficient to provoke an erythema, larger doses will also fail Also, if one or two months of irradiation do not prove efficacious, there is no use in continuing the treatment There may be a defluvium of hair, but the alopecia is usually temporary. Erythema is to be avoided

Pruritus Vulvæ.—The technic for irradiating the vulva is given under the preceding heading. The patient should understand that there may be a temporary loss of hair. There is no danger to the ovaries with the dosage used in practice for this purpose. Occasionally it is necessary to separate the labia majora. This the patient may do herself with the fingers or the parts may be held apart by means of gauze or cork.

Pruritus Scroti.—When treating pruritus of the scrotum with *x*-rays care must be had not to injure the testes. It is safe to administer three or four weekly unfiltered treatments to one surface of the scrotum. If more than this amount of radiation is required, as may be the case, the semen should be examined at weekly intervals and the patient should be told of the possibility of azoospermia. Even when it is necessary to push the treatment to the point of reducing the spermatozoa numerically or to complete azoospermia there will, as a rule, be complete regeneration upon cessation of treatment. It is possible, of course, to effect permanent azoospermia. The exact quantity necessary for this purpose is unknown to us. The dermatologist or roentgenologist should not accept this responsibility. In every refractory case the patient should be made acquainted with the risk, his semen should be examined before institution of treatment and at frequent intervals during the treatment. Men who have suffered for years with severe pruritus scroti will, as a rule, willingly assume the risk of permanent azoospermia, especially if they are beyond middle life, as is often the case.

An unscreened flat radium applicator may be used for the treatment of pruritus scroti. A half-strength unscreened applicator applied for one or two minutes once weekly to one area after another, until the entire scrotum has been treated, will often suffice for a clinical cure. The quantity of gamma and "hard" beta rays reaching the testicle will be insufficient for the production of azoospermia if such treatment is not continued for more than about a month. If the dose is larger than that just mentioned there is danger of injury to the skin. Furthermore, when applying radium to any one part of the scrotum the testicle can be pushed to one side.

It is seldom necessary to apply *x*-rays to both the anterior and the posterior surfaces of the scrotum because the radiation will penetrate in sufficient quantity to the opposite surface.

When irradiating the scrotum it is a good idea to push the testicles into the inguinal canal where they may be held by the patient. Both the hands and the testes can be covered with lead rubber. Even here, however, some scattered radiation is likely to reach the testicles. Regardless of methods of protection it is unsafe to apply much radiation without testing the semen. And it is worth repeating that it is a splendid idea to examine the semen before beginning the treatment.

Very "soft" *x*-rays (grenz rays) might be used to advantage for the treatment of pruritus scroti.

Radicular Roentgen Therapy.—Zimmern and Cottenot recommend what they term "radicular radiotherapy" for pruritus and neuralgia The method consists of applying *x*-rays to the region of the emergence of the spinal nerves They claim success in sciatica, brachial neuralgia, neurodermatitis and psoriasis (paravertebral roentgen therapy, see Chapter on Lichen Planus).

Radium.—The use of radium for the treatment of pruritus scroti has been already discussed. We have had very little experience with radium in regional pruritus essentialis of other parts. Occasionally we have placed a tubular radium applicator in the anus, together with the application of *x*-rays externally (cross fire) Also we have tried beta rays of radium in cases where *x*-rays have failed, the results were negative In general, what has been said relative to the treatment of regional prutitus with *x*-rays pertains also to radium

Wickham and Degrais, Bayet, Schiff, Knox, Newcomet, Finzi, Simpson, Vignolo-Lutati and others have reported good results with radium.

PRURIGO.

Prurigo Nodularis.—Zeisler treated a case of prurigo nodularis with *x*-rays The case was benefited but it was not cured Trimble failed to note relief in 1 case Netherton failed in 2 cases with *x*-rays and radium, even after causing first and second-degree reactions. C J. White treated a case of lichen obtusus corneus, in which a diagnosis of prurigo nodularis was considered *X*-rays were not beneficial We have treated 2 cases with *x*-rays and one with radium with disappointing results.

Prurigo Mitis.—Schultz has roentgenized cases of prurigo of Hebra and has obtained relief from the itching and eruption for periods of from four to six weeks. Hahn and Belot report clinical cures Scholtz failed to note any effect in one case and improvement in several others. We, several years ago, tried *x*-rays in a number of cases of prurigo mitis The lichenification and patches of secondary eczema disappeared. The itching was relieved and there were fewer new lesions The effect was evanescent. It is doubtful if *x*-rays are of any value in prurigo mitis

BIBLIOGRAPHY

ALLEN, C W Radiotherapy and Phototherapy, Philadelphia, Lea & Febiger, 1904, p 247

BAYET, A Quoted by SCHIFF, E Loc cit, p 398

BELOT, J Radiotherapy in Skin Disease, Translated from the 2d French ed by W. Deane Butcher, London, Rebman, 1905, p 279, 282, 290

FINZI, N S. Radium Therapeutics, London, Henry Frowde, Hodder & Stoughton, 1913, p 63

FOX, H The Coolidge Tube in the Treatment of Nonmalignant Diseases of the Skin, Jour Cutan Dis, 35, 599, 1917

FREUND, L Elements of General Radiotherapy for Practitioners, Translated by G H Lancashire, New York, Rebman, 1904, p 298

GOCHT Therapeutische Verwendung der Röntgenstrahlen Fortschr a d Geb d Röntgenstrahlen, 1, 14, 1897

GRUNMACH E Ueber die diagnostische und therapeutische Bedeutung der X Strahlen fur die innere Medicin und Chirurgie Deutsche med Wchnschr 25 604 1899

HAHN R Die Rontgentherapie bei Ekzem Psoriasis Rosacea Acne Vulgaris und Prurigo Fortschr a d Geb d Rontgenstrahlen 5 39 1901

HAILEY HOWARD and HAILEY HUGH Pruritus Ani et Vulvæ Arch Dermat & Syph 40 726 1939

KNOX R Radiography and Radiotherapeutics 2d ed New York The Macmillan Company 1917 1918 vol 2 p 446

KROMAYER Die Behandlung des Pruritis cutaneous insbesondere des Pruritis ani Deutsche med Wchnschr 34 59 1908

LEONARD C L Quoted by NEWCOMET W S Loc cit p 276

NETHERTON E W Prurigo Nodularis Arch Dermat and Syph 8 193 1923

NEWCOMET W S Radium and Radiotherapy Philadelphia Lea & Febiger 1914 p 184

OLLMANN L Idiopathic Pruritus of Ten Years Duration Cured by Radiotherapy Jour Cutan Dis 25 378 1907

PUSEY W A and CALDWELL E W The Practical Application of the Roentgen Rays in Therapeutics and Diagnosis 2d ed Philadelphia W B Saunders Company 1904 p 389

SCHIFF E Radiumtherapie der Hautkrankheiten In Handbuch der Radium Biologie und Therapie (Lazarus) Wiesbaden Bergmann 1913 p 391

SCHOLTZ W Ueber den Einfluss der Rontgenstrahlen auf die Haut in gesunden und kranken Zustande Arch f Dermat u Syph 59 89 241 421 1902

SCHULTZ F X Ray Treatment of Skin Diseases Translated by James Burnet New York Rebman 1912 p 110

SIMPSON F E Radium in the Treatment of Cancer and Various Other Diseases of the Skin Jour Am Med Assn 67 1508 1916

STEMBO L Ueber die schmerzberuhigende Wirkung der Rontgenstrahlen Therap d Gegenw n s 2 250 1900

TRIMBLE W E in discussion on Williams C M Prurigo Nodularis Jour Cutan Dis 34 607 1916

VIGNOLO-LUTATI C Il radium nella terapia del prurito vulvare Gior ital d mal ven 49 930 1914

WHITE C J Lichen Obtusus Corneus—an Unusual Type of Lichenification Jour Cutan Dis 25 385 1907

WICKHAM L and DEGRAIS P Radiumtherapy Translated by S Ernest Doré London Cassell 1910 p 276

WILLIAMS F H The Roentgen Rays in Medicine and Surgery 2d ed New York The Macmillan Company 1903 p 612

ZEISLER J A Case of So-Called Prurigo Nodularis Jour Cutan Dis 30 654 1912

ZIMMERN A and COTTENOT P Radicular Radiotherapy Ref Med Rec 98 564 1920

CHAPTER XXXII.

DISEASES OF THE APPENDAGES.

In this chapter will be discussed hyperidrosis, bromidrosis, chromidrosis, granulosis rubra nasi, hydrocystoma, alopecia areata, alopecia prematura, pompholyx, cheilitis glandularis and cheilitis exfoliativa The last is not a disease of the appendages. It is similar if not identical to seborrheic dermatitis. Both forms of cheilitis are considered in this chapter solely for convenience Many diseases of the appendages are considered in other chapters. Tinea capitis, tinea barbæ, onychomycosis, onychia, favus, acne vulgaris, sycosis vulgaris, hypertrichosis, oily seborrhea, alopecia cicatrisata, various types of folliculitis, etc., are contained in the various chapters and may be located with the aid of the index.

HYPERIDROSIS.

Pusey, in 1901, on theoretical grounds, suggested the use of x-rays for excessive sweating. Engman cured a case of hyperidrosis of the axillæ in 1903 In the same year Stelwagon cured excessive sweating of the palms. Pirie reports the permanent cure of 15 cases of hyperidrosis of the axillæ, hands and feet, with from four to six suberythema treatments at intervals of one month.

In recent years there have been but few reports dealing with the x-ray treatment of hyperidrosis

It is now admitted by all that roentgen therapy will not only overcome excessive sweating in localized areas, but that such procedure constitutes the only certain method of permanently curing the condition.

To cure hyperidrosis it is often necessary to irradiate until there is considerable atrophy of the sweat glands When this has been accomplished there is likely to be more or less atrophy of other appendages and of various parts of the true skin. This atrophy may or may not be manifested by slight wrinkling. In any event it is deemed unwise to treat hyperidrosis of the face on account of the possibility of visible wrinkling Slight atrophy of the skin of the face is likely to be disfiguring, especially when the person laughs or smiles. A much greater amount of atrophy will not be noticeable in the axillæ or on the hands and feet Furthermore, the skin of the face seems to undergo atrophy more easily than does the skin of other parts.

Hyperidrosis of the scalp cannot be treated with x-rays because such treatment would probably result in permanent alopecia

It is considered unwise to treat generalized hyperidrosis with x-rays because such a large amount of radiation might deleteriously affect the deep lymphatic structures, the blood, viscera, etc. One should always consider the possibility of objectionable and even dangerous late sequelæ. Dosage, technic and dangers are discussed later

Rarely one sees localized hyperidrosis in unusual locations—cheek, forehead, or a single round area on the back, or on one arm or leg Such circumscribed areas can be successfully treated with x-rays or radium

The most marked examples of hyperidrosis are usually seen in the axillæ, on the palms and on the feet, especially the plantar surfaces The result of intelligent irradiation in hyperidrosis of these regions is often satisfactory

Excessive Dryness —It is important not to cause complete atrophy of the sudoriferous glands This cannot be avoided with absolute certainty, but it can be prevented in most of the cases While it is true that an excessively dry skin is preferable to an excessively moist skin, yet the former has its disadvantages We have seen cases of excessively dry skin of the axillæ, palms and feet that required constant applications of grease Without plenty of oil the skin fissured and eczematized very easily, especially in cold weather The treatment, therefore, should proceed cautiously, and it should be interrupted before sweating has entirely ceased After cessation of treatment the secretion will usually continue to diminish for a few weeks and the skin may become temporarily too dry This is followed by considerable regeneration, so that the end result is a skin exhibiting the normal amount of moisture Roughly, the treatment should be stopped when there has been 75 per cent improvement After a rest of two or three months, if there is still too much sudoriferous activity, more treatment may be given Irradiation may cure hyperidrosis, but there is no successful treatment for the excessively dry skin that may follow complete atrophy of the oil glands and sweat glands

Patients will become impatient and urge the operator to administer larger doses or to give the treatments at shorter intervals Is it necessay to caution the reader that he must be guided entirely by his own judgment, which should be based on a knowledge of the disease and an adequate knowledge of x rays and radium? If so, it is requested that the reader peruse carefully the medicolegal chapter Examine the skin carefully, and interrogate the patient at each visit Stop the treatment before sweating is entirely arrested There are instances when sweating stops suddenly after one or several treatments In such cases no more treatment should be administered As a rule, the reduction of sudoriferous activity is gradual

Dosage —Regional hyperidrosis may be cured in one treatment by administering a quantity of radiation that will effect a first-degree reaction Such treatment is decidedly inadvisable It may cause too much atrophy and it may be followed by telangiectasia We have seen some good results from such treatment and we have also seen a number of bad late results

Most dermatologists apply 75 r, unfiltered, once weekly without interruption up to sixteen treatments if necessary This is safe treatment and the results are often satisfactory It is the treatment used

by us as a routine. Some operators give monthly treatments. The flexures (axillæ, palms and soles) are rather sensitive parts ("radiosensitive") and, therefore, the dose should be less than for other parts of the body. The soles will tolerate a little more than will the palms, and the latter will stand a little more than will the axillæ. The sex, age and complexion of the patient must also be taken into consideration. The usual dose is 225 r, once monthly. There are exceptions· in adolescents, females and blonds the first dose is 150 r. Old people or very dark persons may tolerate 250 r or more. It rarely requires more than six treatments to effect the desired result. Many patients are cured in four treatments and a few patients are cured in one or two treatments.

A first-degree reaction should be avoided because of the danger of telangiectasia Larger individual doses or a greater total dose than herein advised should be avoided because of the possibility of the subsequent development of *x*-ray skin.

Technic.—*Axillæ.*—The patient should be on his back on the table, the forearm is placed behind the head. This will expose and tend to flatten the concave axilla The anode is placed directly over the center of the axilla; all parts excepting the axilla are carefully shielded In most persons it is impossible to convert the axilla into a plane surface. With the position given above there will be still a little concavity. This slight concavity, however, is not a disadvantage, as it favors equalization of dosage of the entire surface.

There may be temporary loss of axillary hair and occasionally there is pigmentation.

Palms.—Both palms may be exposed at one time The hands are held close together with the dorsal surfaces of the hands and fingers in contact with the table. The anode is placed directly over the center of the area to be irradiated. It is obvious that the dose will not be equal over this large surface unless the tube is placed at a much greater distance than is used in practice. This accounts for the apparent stubbornness of hyperidrosis of the finger tips If the hands are flexed a little so that the periphery of the exposed surface is a little nearer than is the center, then all the rays, direct and oblique, will travel the same distance and the dose will be equalized over the entire surface. It is difficult to estimate the exact amount of flexion required, and if this feature is correctly estimated it is extremely unlikely that the hands will remain in a fixed position during the exposure. If there is too much flexion the finger tips will receive too much radiation

Pirie has devised an ingenious apparatus for this purpose. It consists of a sheet of heavy celluloid shaped like a half bowl. The backs of the hands are placed on the operating table with the palms and fingers of both hands in contact with the convex surface of the bowl The shape of the apparatus is based on the law: intensity varies inversely as the square of the distance or directly as the sine of the angle of incidence. The anode is placed directly over the center of the bowl.

As a general thing it is preferable to treat each hand separately.

Feet.—Hyperidrosis of the feet may be confined to the soles or it may involve the lateral and even the dorsal surfaces. It is not a simple matter to equalize the dose over these uneven, convex and rather extensive surfaces.

The soles can be irradiated by having the patient lie face down on the table. The dorsal surfaces of the feet rest on the table. A sandbag placed under the ankles will add to the patient's comfort. A still better plan is to place the dorsal surfaces of the feet on an inclined plane. Both feet are held close together. The tube is placed so that the direct rays are perpendicular to the plane of the surface to be irradiated, the target being directly over the center of this surface.

This does not give equal quantity over the entire surface, but it answers practical requirements in most instances. If the feet are large it may be necessary to treat first one-half of the plantar surface and then the other half, care being taken not to expose any part of the surface twice.

If it is necessary to expose the lateral and anterior aspects of the feet as well as the soles, the following procedure may be adopted. After treating the soles the foot is placed so that its outer surface rests on the table. The target is placed over the tubercle of the navicular bone. The foot is then allowed to rest on its external surface and the target is placed over the articulation between the scaphoid and internal cuneiform bones. Each of these exposures is to be at right angles to that for the soles, and each foot is to be separately treated. No protection is necessary. The oblique rays from all the exposures are allowed to overlap. The ankles and legs of course should not be included in the field of radiation. It is customary to reduce the dose from 75 r to about 35 r because of overlapping.

Filtration.—There is no objection to filtration, but we have failed to note any therapeutic advantage when employing filtered radiation. To give arguments for and against filtration will be but to repeat what has been said in other parts of this work.

Radium.—We have not employed radium in the treatment of hyperidrosis because *x*-rays are more suitable for the rather extensive surfaces that are usually involved. No literary references have been located. Unquestionably gamma or "hard" beta rays will prove as efficacious as are the *x*-rays in this condition.

BROMIDROSIS

Bromidrosis may be general or regional. It is most often regional, the sites of predilection being the axillae and feet. It is usually associated with hyperidrosis. Regional bromidrosis can usually be relieved and at times entirely cured by irradiation. The technic is the same as outlined for hyperidrosis. Lieberthal cured a case of bromidrosis

in 1910. Ormsby, Pusey, Sutton and many other dermatologists and roentgenologists have found x-rays of service in this unpleasant condition.

CHROMIDROSIS.

We treated one case of this disease with unfiltered x-rays. The involved area was about the size of a silver dollar, bluish in color and situated on the right side of the face of a young adult brunette. The area seemed to be slightly edematous or soggy. The sweat from this area was blue. The treatment consisted of 75 r each week There was little if any improvement after eight treatments.

GRANULOSIS RUBRA NASI.

There has been no personal experience with x-rays or radium in the treatment of this disease. Pusey, Sutton and others suggest the use of these agents Brandle found the x-rays efficacious Winfield noted improvement with x-rays in one case

HYDROCYSTOMA.

Max Joseph and Conrad Siebert cured a case of hydrocystoma tuberosum multiplex with x-rays. We have cured several cases In two instances the lesion returned in a few months. The end result in the others is unknown. In one case there was no improvement after three suberythema applications of unfiltered x-rays to one lesion.

CHEILITIS.

Cheilitis Glandularis.—Zeisler and Sutton noted substantial improvement in cases of cheilitis glandularis treated with x-rays.

Cheilitis Exfoliativa.—Hyde, Gilchrist, Ravitch, Howard Fox, Morris, Ormsby, Sutton and others have cured cases of cheilitis exfoliativa with x-rays. We have treated several cases with x-rays In each instance a single suberythema dose effected a prompt clinical cure. As far as is known there were no recurrences Sutton cured one case with one application of radium.

It should be remembered that the mucous membrane of the lip is more sensitive to irradiation than is the skin of the face; therefore the dose should not be large. If a cure by a single treatment is attempted the dose should not be over 225 r, unfiltered. Weekly treatments of 75 r will undoubtedly give the same results. It is well to keep in mind that many cases of cheilitis are examples of dermatitis venenata.

POMPHOLYX.

Pompholyx (dysidrosis; cheiro-pompholyx) is a disease that is often confused with dermatophytosis, dermatophytid and dermatitis venenata. In fact it is possible that pompholyx and dermatophytosis

are the same For this reason one must be careful in giving evidence for or against the efficacy of irradiation in the treatment of this condition—in other words, it is necessary to be reasonably certain of the

Fig 193 —Hydrocystoma before x ray treatment

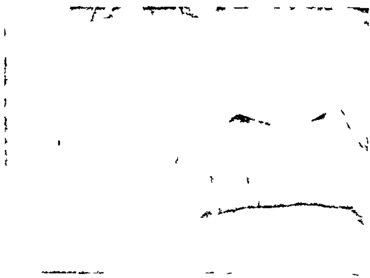

Fig 194 —Same as Fig 193 after six unfiltered x ray treatments of 75 r each administered at weekly intervals

diagnosis Another difficulty is that pompholyx is a self-limited disease which may endure for a few days weeks or months Yearly recurrences are common

We have a record of 20 cases of pompholyx that were treated with

JOSEPH, M, and SIEBERT, C Ueber erfolgreiche Behandlung des Hidrocystoma tuberosum multiplex, Dermat Wchnschr, 56, 425, 1913
KIENBOCK, R Quoted by Freund, L Elements of General Radiotherapy for Practitioners, New York, Rebman, 1904, p 272
LIEBERTHAL, D Bromidrosis, Jour Cutan Dis, 28, 421, 1910
MORRIS (SIR), M A Diseases of the Skin, 6th ed, London, Cassell, 1917, p 618
NEUMANN, J Quoted by Freund, L Elements of General Radiotherapy for Practitioners, New York, Rebman, 1904, p 274
ORMSBY, O S, and MONTGOMERY, H A Practical Treatise on Diseases of the Skin, 6th ed, Philadelphia, Lea & Febiger, 1943, pp 1129, 1277
PIRIE A H *Excessive Local Perspiration, an Account of the Successful Treatment* of Fifteen Cases, Lancet, 2, 433, 1911
PUSEY, W A Roentgen Rays in the Treatment of Diseases of the Skin, Jour Am Med Assn, 37, 820, 1901
———— The Principles and Practice of Dermatology, 4th ed, New York, Appleton, 1917, p 950, 959
RAVITCH, M L Cheilitis Exfoliativa, Jour Cutan Dis, 26, 359, 1908
SIMPSON F E Radium in Skin Diseases, Jour Am Med Assn 61, 80, 1913
STELWAGON, H W Some Observations on the Use of Roentgen Rays in Dermatology, Jour Cutan Dis, 21, 345, 1903
SUTTON, R L Diseases of the Skin, 2d ed, St Louis, Mosby, 1917, p 848
———— Cheilitis Glandularis Apostematosa (with Case Report), Jour Cutan Dis. 27, 150, 1909
WINFIELD, J M Granulosis Rubra Nasi, Jour Cutan Dis, 38, 177, 1918
ZEISLER, J Cheilitis of the Upper Lip, Jour Cutan Dis, 33, 104, 1915

CHAPTER XXXIII

HYPERTRICHOSIS

Historical —To Freund should be given the credit of being the first to remove superfluous hair with x-rays He depilated a nevus pilosus by this means In fact this was the first case of any disease or condition to be treated with x-rays—the beginning of roentgen therapy Later, Freund, together with Schiff, reported a series of cases of hypertrichosis of the face which they had cured with this new treatment This report was followed by similar ones by Benedikt, Walsh, Ehrmann Holzknecht Kienbock Noire Bordier and, in fact, by nearly all the early roentgenologists In this country Pusey was the pioneer with Zeisler and Allen as close seconds

The early workers were enthusiastic over the results obtained, but very soon it was discovered that a large percentage of the cases developed x-ray sequelæ—atrophy, telangiectasia, scarring and keratoses In the beginning, roentgenologists while desiring to avoid a third-degree radiodermatitis did not hesitate to evoke an erythema or even a second degree reaction In fact, the very first case treated resulted in a severe radiodermatitis Later, when it was found that even a mild radiodermatitis might leave disfiguring sequelæ and that it was difficult to avoid these mild reactions, enthusiasm waned

Then came radiometric methods of measurement and improved technic Again the work was undertaken with enthusiasm but this time with caution The literature of the time is voluminous with reports of the excellent results obtained However optimism did not endure Even with the most accurate technic bad results were common It was soon ascertained that it was impossible to remove permanently superfluous hair from the face without the risk of at least visible wrinkling

From 1904 until 1925, and even later there was a controversy as to the propriety of treating superfluous hair with either x-rays or radium At first, half the dermatologists favored the method while the other half condemned it The same was true of roentgenologists Also there were a number of dermatologists who changed their minds from time to time For instance, Albert Geyser was at first an advocate of this method Later he condemned it irrevocably Later still, he organized the tricho institute' which, fortunately was compelled to cease functioning ten or fifteen years ago We still see many cases of severe chronic radiodermatitis and cancer caused by treatment given at the 'tricho institute" Another New York physician first favored and used x-rays for this purpose After a number of untoward results he published a condemnatory article Subsequently, because

of improved technic and encouraging literary reports, he again undertook the work. The result was disastrous—cases of chronic radiodermatitis and legal actions decided in favor of the plaintiff.

Present Day Opinion.—It is now the consensus of dermatologists and roentgenologists that superfluous hair can not be permanently removed with radiation of any kind, regardless of technic, without permanent injury to the skin. In fact this opinion is unanimous. Permanent injury means chronic radiodermatitis (*x*-ray skin or radium skin). A few lucky persons may never develop sequelæ. Some may have no more than a little atrophy (wrinkling). Many will develop more or less, usually more, telangiectasia in a year or two; and many will, after five or ten years, show telangiectasia, atrophy, sclerosis, pigmentation, depigmentation, and keratoses. And 25 or 30 per cent of these individuals will eventually have epithelioma of the prickle-cell (malignant) type.

It is therefore the consensus of modern professional men and scientists that radiation of any kind is contraindicated for the treatment of hypertrichosis unless the situation is exceptional.

The reader may well ask what may constitute the exception. Possibly there should be no exception. Nevertheless, there is an occasional person, usually a female, rarely a male, who is unable to accept the affliction philosophically. She will become psychopathic or have a permanent nervous collapse unless something is done. Some such patients may obtain a satisfactory result with electrolysis or with the more modern electrocoagulation, some can not. Others may be controlled by a psychiatrist Rarely it may be advisable to use *x*-rays, but only after a consultation with the family medical adviser, another dermatologist and a psychiatrist. It is for this possible exception that we consume space for the technic.

Some cases of hypertrichosis, either because of extensiveness or because the hair is of the lanugo type, can not be overcome by any method known at present. Patients ascertain that such hair can be permanently removed with *x*-rays. They desire the treatment, they are willing to accept any risk, so they say and believe at the moment, and they may make a desperate, pathetic and seemingly logical appeal for the treatment. The physician should be understanding and sympathetic, but he should be guided by knowledge and advice, not by the pleas of the patient.

Results Obtainable with X-rays.—It may interest the reader to know just what can be accomplished with modern technic. A combination of modern technic and skilled operator reduces the danger of a third- or even a second-degree acute radiodermatitis to a minimum. An amount of radiation sufficient to effect a defluvium of face hair, unfiltered, filtered, single epilatory dose or fractionated treatment, will very often evoke erythema of the face. In fact, erythema usually occurs. A certain percentage of first-degree reactions is followed by telangiectasia, possibly to the extent of 10 per cent. Also, a certain

percentage is followed by atrophy This percentage is not known It may be in the neighborhood of 75 per cent It is possible to avoid even a mild first-degree reaction but not with certainty

But let us assume for the sake of argument that an erythema can be avoided What will be the result? In order to remove hair permanently from the face it is necessary to cause complete destruction of the hair bulbs and papillæ Regardless of the method of application when an amount of radiation sufficient to effect permanent atrophy of these parts has been administered, there is bound to be more or less atrophy of elastic tissue collagen etc Whether the atrophy of the derma will be sufficient to effect visible wrinkling is impossible to say until a year or two after the last treatment The amount of such atrophy depends both upon the amount of radiation and upon idiosyncrasy The visible wrinkling depends partly upon personal peculiarities For instance, a coarse skin will tolerate a greater amount of radiation without atrophy and a greater amount of atrophy without visible evidence of such atrophy than will a fine-textured, fair skin Wrinkling may not be manifest until the patient is thinner, older or both

Various physicians have different ideas of good results and so do patients The atrophy mentioned above is not noticed in the axillæ and on various parts of the body, and it may not be noticed on the face when in repose But when expressing the emotions, even when talking, the evidence of atrophy may become very noticeable, especially around the mouth It is this type of atrophy that is difficult to avoid One cannot insure against this sequela regardless of the technic Of greater importance is the possibility, even the probability, of severe chronic radiodermatitis from five to fifteen years after the treatment A quantity of x rays or gamma rays sufficient to prevent the growth of all hair permanently especially that of the downy type, is almost certain to lead to such sequela We have seen some hair growing in x-ray skin subsequent to a second-degree acute radiodermatitis

Medicolegal Aspects —Many physicians believe that if they explain the risks of x-rays and radium for the treatment of hypertrichosis of the face to the patient and the latter understands and accepts the risk, the physician cannot be held responsible for bad results This is not true There is nothing that can prevent the institution of a suit for mal practice if the patient desires to bring such suit Not even a signed witnessed and sworn statement in which the patient states that she or he appreciates and accepts the risk can prevent the suit, although such statement may have a favorable influence upon the jury

The verdict rests almost entirely upon the question of negligence, at times on implied or expressed contract The burden of proof is on the plaintiff (patient) The patient must prove that the defendant (physician) failed to employ the skill, judgment, care technic etc, as used under like circumstances by the average specialist in the same line in the same community and epoch The fact that the plaintiff

understood and assumed the risk does not negative negligence on the part of the defendant. If the defending physician used a method of treatment that has been and is advocated by specialists in good standing, and his judgment and technic were in accordance with the required standards of his profession, *i. e.*, absence of negligence, then he is immune insofar as damages are concerned.

The majority of dermatologists and roentgenologists are either opposed to the treatment of hypertrichosis with *x*-rays or radium or they reserve such treatment for exceptional cases

Hypertrichosis patients are exceedingly friendly when seeking relief, and are ready to "grasp at a straw," but many of them become exceedingly bitter and revengeful if they develop *x*-ray sequelæ. *X*-ray treatment appeals to the patient because there is no temporary disfigurement, no pain nor discomfort, because there is economy of time and particularly because the effect is permanent. The method is so attractive and the appeal is so great that the patient is likely to belittle the statements made relative to the danger of *x*-ray sequelæ. They fail to visualize the result At this time they are perfectly willing, they say, to have a little wrinkling substituted for the repulsive hair. But a year or two later, long after the hair has disappeared, and wrinkling has occurred, they realize they have a defect that cannot even be hidden. They forget their original appearance and anguish, they feel that they were deceived and they seek revenge; and often the case is within the legal statute of limitation.

The physician must be exceedingly careful not to allow the pleadings of a patient before or during treatment to interfere with his judgment. Furthermore, if he undertakes the treatment he should be absolutely certain that the patient is made to realize the possible end results He should never take it for granted that the patient is a "good sport" and will overlook an accident or unavoidable sequelæ. Finally, the physician should understand thoroughly that, while absence of proof of negligence will make it difficult if not impossible for the patient to collect damages, there is nothing that can prevent the institution of a malpractice suit. For further medicolegal details the reader is referred to the medicolegal chapter.

Technic (X-rays).—It is difficult, almost impossible, with filtered or unfiltered radiation, to effect a complete or even a partial defluvium of face hair with one treatment without causing an erythema An erythema (mild first-degree reaction) must, of course, be avoided if possible. As a rule, it requires more radiation to depilate face hair than is required for defluvium of scalp hair. The unfiltered child's scalp epilating dose (300 r) will effect defluvium of scalp hair without effecting a skin reaction, but this amount of radiation applied to the face provokes a reaction.

After depilation, unless the treatment is continued, the hair will return in from one to three months It is customary, therefore, to repeat the treatment about every six weeks with smaller doses (150 to

225 r) for a total of from four to six treatments Such treatment will usually suffice for total and permanent destruction of the hair follicles

By applying 75 r unfiltered once a week the hair may eventually fall out and not return This will require in the neighborhood of eight months to a year or more There will be no reaction but, of course there is very likely to be atrophy This technic is hardly ever employed for this purpose

A better method, perhaps is to administer 75 r unfiltered every three four or five days, until the hair falls After the hair is out it is often necessary to give every five or seven days 75 r unfiltered for from six to eight months or even a year in order to prevent a return of hair

Face —The x-rays may be applied to the face by the four-exposure method as described by Kienbock A detailed description of this method will be found under the heading of Tinea Barbæ

Axillæ —The method of applying x-rays to the axillæ will be found under the heading of Hyperidrosis

Trunk —It is a difficult matter to obtain uniform dosage over extensive and irregular surfaces We have treated men who had a very heavy growth of coarse black hair scattered over the chest shoulders arms and upper back In such instances multiple exposures are made as follows The tube is centered over the anterior axillary fold of first one side and then the other side on about a level with the nipple, the two treatments must be at least 12 inches apart the oblique rays are allowed to overlap upon the chest The same procedure is followed for the upper back Finally, an exposure is made to the external aspect of each arm near the shoulder the incidence being at right angles to the exposures for the chest and back All non-hairy parts are adequately protected with lead foil or other suitable material

Extremities —As a rule the growth of hair is limited to the extensor and lateral aspects of the forearms and, perhaps the backs of the hands To equalize the dose over such a large and convex surface requires six exposures for each forearm With the palm of the hand resting on the table the anode is centered first over the elbow and then over the back of the hand The distance between the two positions should be about 12 inches The same procedure is then followed for each lateral surface providing of course that the hypertrichosis involves these surfaces Only the non-hairy parts are protected A similar method is used for the legs

Danger Signs —At each visit the skin should be carefully tested for evidence of a reaction—even for premonitory symptoms of a reaction Skin that is nearly ready to show visible signs of mild radiodermatitis is usually irritable It will flush readily even upon change of posture or slight pressure It reddens quickly under the influence of heat or even under emotional excitement It is irritable when exposed to wind or sunlight A very good way to determine whether or not one is close to the danger point is to note the erythema produced by slap-

ping or by the application of a folded towel wet with hot water, as compared with the effect produced on neighboring unexposed skin.

At the slightest evidence of reaction, or even in the presence of premonitory symptoms, the exposures should be discontinued temporarily

The patient should be cautioned against doing anything that might increase the effect of the x-rays, such as exposure to the sun and wind, application of stimulating and irritating topical remedies, etc.

Filtration.—The possible advantages of moderately filtered radiation (3 mm Al) are as follows:

1. There may be a little greater latitude between the amount necessary to effect a defluvium and the amount necessary to provoke an erythema
2. There is a smaller proportionate absorption of radiation in the tissue between the surface of the epidermis and the hair papillæ.
3. Telangiectasia may be a little less common after reactions from filtered treatment than after unfiltered treatment

These points are discussed in detail in the Chapter on General Therapeutic Considerations and need not be repeated here It is well to emphasize, however, that it is necessary to destroy the hair papillæ completely and permanently As stated before in this chapter, when an amount of radiation, even filtered radiation, sufficient to destroy the follicles has been administered, there will be at least some atrophy, and there is about the same probability of severe late sequelæ as with unfiltered radiation We have tried both filtered and unfiltered x-rays and we have observed little difference The terrible endresults of treatment at the "tricho institute" (filtered radiation) confirms our experience and opinion

High voltage x-rays (several hundred or a thousand kilovolts) filtered through copper or zinc, in quantities sufficient to effect defluvium of hair in glabrous skin, cause a reaction called epidermitis or epithelitis which has been thought to be harmless However, we have seen the same clinical and histopathologic changes after such treatment as those following unfiltered and lightly filtered radiation. Also, there is the danger of serious injury to deeper tissues and organs (see chapters on Clinical and Histopathologic Radiodermatitis)

Radium.—In a general sense, what has been written in this chapter relative to the use of x-rays in the treatment of hypertrichosis applies to radium.

BIBLIOGRAPHY

BENEDIKT, H Radiotherapeutische Erfahrungen, Wien med Wchnschr, 51, 515, 1901

BORDIER, H · A Novel Technique for Radio-Therapeutic Epilation, Arch Roentg Ray, 14, 260, 1909–1910

EHRMANN, A Erfahrungen uber die therapeutische Wirkung der Elektricitat und der X-Strahlen, Wien med Wchnschr, 51, 1417, 1466, 1901

FREUND, L · Ein mit Röntgen-Strahlen behandelter Fall von Nævus pigmentosus piliferus, Wien med Wchnschr, 47, 428, 856, 1897

——— Elements of General Radiotherapy for Practitioners, New York, Rebman, 1904, p 229.

GEYSER A C A Resume of Two Hundred Cases of Hypertrichosis Treated with the Roentgen Ray Jour Cutan Dis 33 520 1915

KIENBOCK R On the Radiotherapeutic Treatment of Diseases of the Hair Arch Roentg Ray 12 12 1907 Ueber Radiotherapie der Haarerkrankungen Arch f Dermat u Syph 83 77 1907

——— [Zeigt im Anschlusse daran weitere Erfolge der Radiotherapie bei zwei Kindern mit Favus und einem Fall von Herpes tonsurans capillitii bei dem Pilze sicher nachgewiesen waren] Arch f Dermat u Syph 56 131 1901

NOIRÉ H A Method of Treatment of Hypertrichosis by the X Rays Brit Med Jour 2 1259 1908

PUSEY W A The Principles and Practice of Dermatology 3d ed New York Appleton 1917 p 1160

PUSEY W A and CALDWELL E W The Practical Application of the Roentgen Rays in Therapeutics and Diagnosis 2d ed Philadelphia W B Saunders Company 1904 p 351

SCHIFF E and FREUND I Beitrage zur Radiotherapie Wien med Wchnschr 48 1057 1118 1177 1898

WALSH, D The Removal of Superfluous Hair by a Combination of X Ray Exposure and Electrolysis Lancet 2 1191 1901

CHAPTER XXXIV.

DISEASES OF THE HEMATOPOIETIC SYSTEM.*

THE diseases that will be discussed in this chapter are:

1. Granuloma Fungoides.
2. Leukemia Cutis.
3. Lymphadenosis Cutis
4. Hodgkin's Disease.

GRANULOMA FUNGOIDES (MYCOSIS FUNGOIDES).

Scholtz (Germany, 1902) was the first to employ x-rays for the treatment of mycosis fungoides Belot (France), Jamieson (England), and Allen (United States), were the first to use x-rays for this purpose in their respective countries

These initial records were followed immediately by reports by Walker and Brooks, Stainer, Riehl, Marsh, Hyde, Montgomery and Ormsby, Carrier and Pusey. Since these early reports the literature has become voluminous.

Clinical Features.—A controversy exists with respect to granuloma fungoides, not only in its clinical but also in its histopathologic features Some dermatologists of experience and repute often show a tendency to include under the entity known as granuloma fungoides certain generalized and universal erythrodermas sometimes associated with lichenification not accompanied by any characteristic blood change, and probably related to the so-called "aleukemic" leukemides, to pityriasis rubra of Hebra, or to dermatitis exfoliativa These generalized erythrodermas certainly do not respond to roentgen therapy, as does granuloma fungoides As a rule, the lichenification, if it exists, will subside under roentgen therapy, but complete retrogression, as occurs so frequently in granuloma fungoides, is the exception rather than the rule

The roentgenologist should be acquainted with the behavior of granuloma fungoides when irradiated and when not irradiated The reader is advised to study the disease in any standard textbook on dermatology. Only the essential features will be mentioned here.

The disease begins usually with an eruption that may resemble eczema, psoriasis, parapsoriasis, neurodermatitis, sarcoma, leprosy, lymphoblastomas and certain drug eruptions. This is the prefungoid stage. The eruption is almost always pruritic, the itching, as a rule, being intense. The individual lesions consist of dusky-red, scaly patches of various sizes During the evolution of the eruption, old

* In the last edition, this chapter was revised by Dr Fred Wise Some of the material added by Dr. Wise has been retained in this edition

lesions may undergo spontaneous involution and there may be periods of quiescence More commonly new lesions continue to appear until the eruption is generalized The prefungoid stage may be of several years' duration it may endure for only a few weeks or months, or it may be entirely absent In the last instance the disease begins with infiltrated plaques nodules or tumors

The fungoid stage is represented by nodules and tumors that range in size from a pea to a cocoanut The lesions may be firm, smooth tumors or they may ulcerate and form large fungating masses The lymphatic glands enlarge the patient becomes cachectic and death follows from septicemia toxemia, exhaustion or death may be due

Fig 197 —Granuloma fungoides (prefungoid stage) before treatment

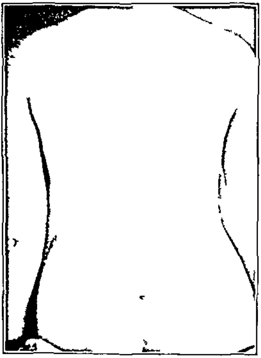

Fig 198 —Same patient shown in Fig 197 after generalized roentgenization

to visceral involvement Tumors occasionally regress spontaneously either by suppuration or by resolution and absorption but new lesions continue to develop

The prognosis is practically hopeless excepting as to prolongation of life by therapy The patient may live from a few months to twenty years the average being from two to four years

After the development of tumors the patient usually succumbs in a few months or at most in two or three years There have been but 3 cases of permanent cure on record One cure followed an attack of erysipelas 2 others followed the administration of arsenic (Bazin, Kobner, Geber)

Effect of X-rays and Radium on Prognosis.—We have failed to find a single report of a permanent cure of granuloma fungoides with *x*-rays or radium. The early literature contains a number of reports of clinical cures without recurrence for a year or two. Sequeira (1914), in an excellent article on granuloma fungoides in which he reviewed the literature, failed to find a single case of the disease that had been permanently cured with *x*-rays. The discussion following the paper

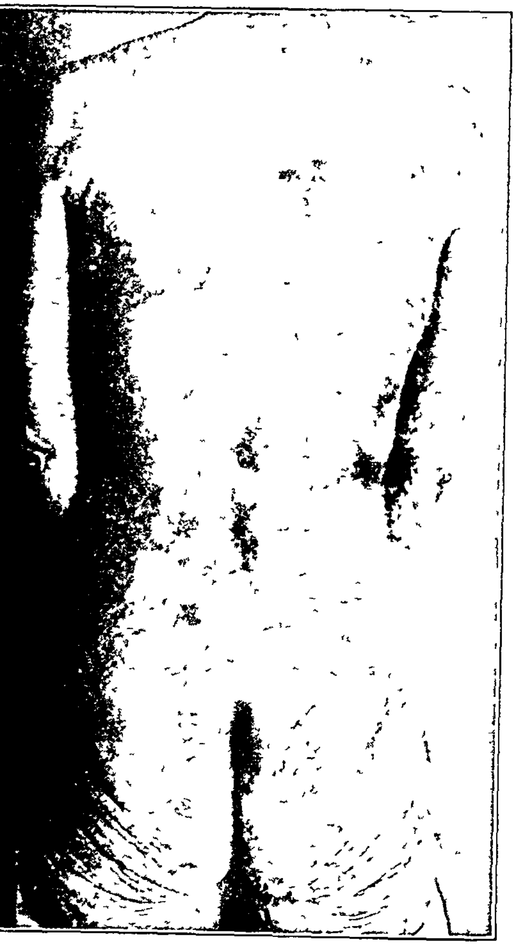

Fig. 199.—Granuloma fungoides (prefungoid stage) before treatment.

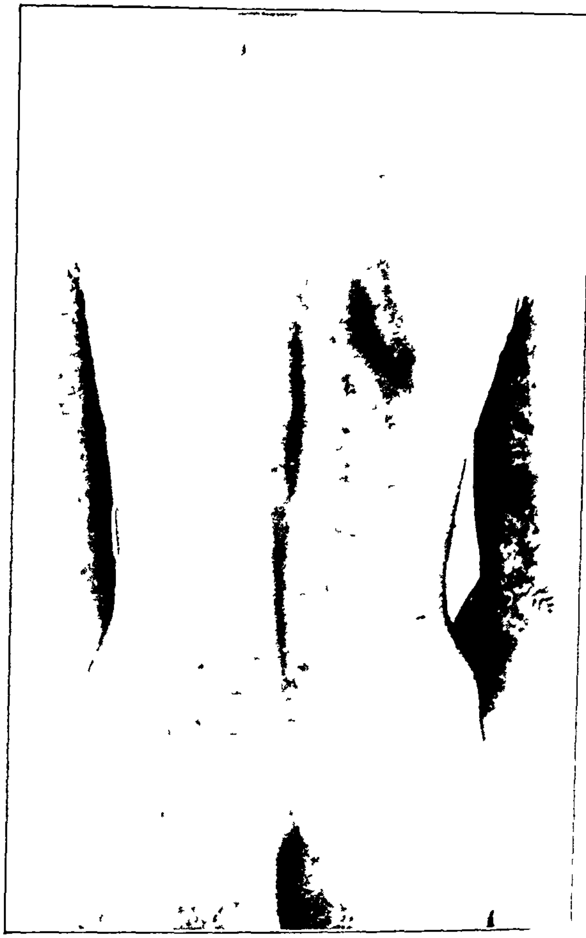

Fig. 200.—Same patient shown in Fig. 199, after generalized roentgenization.

was brilliant. All the speakers (Pringle, Malcolm Morris, McDonagh, Galloway, Stowers, Abrahams, Whitfield, Pernet, Graham Little, MacLeod and Dore) were of the opinion that *x*-rays could not be depended upon to eradicate the disease permanently, although they might do so rarely. Whitfield reported one case where there had been no recurrence for five years and Sequeira told of a patient who had been free of clinical evidence of the disease for four years. Bisserié obtained 5 "cures" out of 6 cases; in 1 case there was a recurrence, the period of observation was fifteen months.

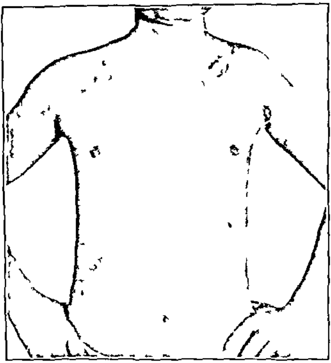

Fig 201 —Granuloma fungoides fungoid stage before treatment

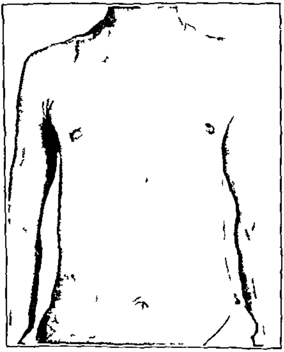

Fig 202 —Same patient shown in Fig 201 after generalized roentgenization

A review of textbooks and articles shows that it is the consensus of dermatologists that *x*-rays and radium are superior to any other known therapeutic agent or combination of such agents for the treatment of granuloma fungoides. Patients may be kept alive and in comfort for years. Such patients, however, eventually succumb to the disease if they have not died of some intercurrent disease in the meantime.

Effect on Symptomatology.—The effect of irradiation on the cutaneous lesions of granuloma fungoides is often spectacular. It is possible (but not advisable) to cause complete involution of the largest tumors or most extensive plaques with one treatment. Patients who are literally covered with lesions, who are suffering intensely from pain and itching, who are in exceedingly poor general health, and who have failed to obtain relief with other remedies, can, in the majority of instances, be clinically cured by the proper use of *x*-rays. What a pity that the relief is not permanent! We have treated cases of granuloma fungoides with *x*-rays and radium. The following description of the action of these agents on this disease is based on personal experience.

To determine the exact value of irradiation in the treatment of granuloma fungoides is not an easy matter. The result seems to depend partly upon technic and judgment and partly upon the disease itself. As we shall see later, there is evidence to support the opinion that the symptoms can be made worse, the disease can be made more malignant, complications can be effected and death can be hastened by improper technic. But first let us assume proper technic and confine our attention to the behavior of different clinical types of the disease.

Cases are encountered in which the *x*-rays seem to be of little benefit. New lesions develop as fast or faster than the old ones disappear. In a few weeks or months the treatment ceases to be beneficial, and the patient succumbs. Fortunately such cases are in the minority. Even in these malignant cases irradiation is of value in temporarily lessening the itching. Rarely, *x*-rays have no effect whatsoever. Wise treated 3 patients having the diffuse, uniformly erythematous type of prefungoid eruption, the so-called "homme rouge" of the French authors; he found this form to be extremely resistant to *x*-ray therapy, both filtered and unfiltered. We have had somewhat the same experience although one of our patients did improve considerably.

It is rather a common phenomenon to observe patients who do fairly well under irradiation, but who are never entirely relieved. These patients, like the former type, usually have a generalized eruption, consisting of erythematous patches, infiltrated plaques and, perhaps, tumor formation. Itching is greatly relieved and may be entirely arrested. The lesions regress in a few weeks but new lesions continue to appear. By more or less constant, carefully conducted irradiation, these patients can be kept comfortable most of the time for several

years Sooner or later, usually in from two to five years, the treatment loses its effect New lesions develop even in locations that are being irradiated Both new and old lesions fail to be benefited, even itching is no longer relieved After x rays cease to be of service these patients die as a rule in a few months

There is a third group of cases the most common of all, in which the patients after a course of x ray treatment, remain asymptomatic for varying lengths of time—from a few months to a year or two The recurrences are readily amenable to irradiation and the patients remain comfortable for several to many years Some patients require several courses of treatment each year while others require only one or a few treatments each year or every two or three years Sooner or later, however the disease fails to yield to the treatment and the patient succumbs

FIG 203 —Granuloma fungoides Vegetating lesions on tongue before treatment

FIG 204 —Same patient shown in Fig 203 after one suberythema x ray treatment

We have had poor results with x rays in cases of "parapsoriasis that later proved to be mycosis fungoides Conversely results have been good in cases of "psoriasis that turned out to be mycosis fungoides

Usually it is impossible to determine the prognosis the first time the patient is examined But after watching the effect of roentgenization for a few weeks or months it becomes possible to place the case in one of the three groups outlined above and hence the prognosis may be determined Generalized eruptions of either the prefungoid stage or the fungoid stage in apparently exceedingly severe cases, will often clear up and the disease will remain under control for many years The same is often true even in cases when the fungoid stage is not

preceded by a prefungoid eruption Conversely, one meets with apparently mild cases that very soon become recalcitrant It is this last type, together with phenomena that will be described later, that has led many to believe that irradiation is the cause of the change from benign to malignant type As will be seen later, injudicious irradiation may effect this undesirable result, but the same thing is noted, not only when the technic is proper, but even when x-rays or radium are not used

Illustrative Case Reports.

Case 1 —Mr J H D, aged sixty-one years The disease first became manifest twenty-seven years ago For the first few years the eruption resembled eczema Twenty-four years ago Howard Fox successfully treated the patient with x-rays for a generalized prefungoid eruption The eruption returned in a few months and again became generalized For a period of two or three years the disease was held in abeyance with x-rays by Dr Fordyce. The patient then came under the care of Dr MacKee For several years there were no erythematous patches but a few nodules would develop two or three times a year These lesions disappeared promptly when irradiated For ten years it was not necessary for the patient to receive x-ray treatment more than twice yearly and during one entire year there were no lesions At one time he developed a nodule that required intensive treatment Previously, every lesion disappeared as a result of a few fractional treatments He died of pneumonia about ten years ago MacCormac and others have reported similar cases

Case 2.—Miss A B., aged thirty-five years. The patient developed a few nodules, the first evidence of her trouble, in 1915—mycosis fungoides d'emblée of the French school The lesions disappeared as a result of three fractional x-ray treatments at weekly intervals. One year later there was a recurrence, the lesions disappearing promptly when irradiated There were no lesions in 1917 and 1918 In 1919 there were two outbreaks, the first consisting of nodules and the second, eight months later, consisting of two erythematous plaques and a few nodules, all of which resolved under a few fractional treatments The last attack required almost double the amount of treatment necessitated by the earlier recurrence. The patient was last seen in August, 1920

These two patients are the most favorable cases we have encountered Most patients require several courses of treatment each year

Case 3 —Mrs B A, aged thirty-three years This patient had had an eruption for two years before x-ray treatment was instituted When treatment was begun the eruption was generalized and consisted of slightly infiltrated scaly and intensely pruritic plaques There have never been any tumors or nodules In spite of carefully administered x-ray treatment the patient was not entirely free of lesions during a period of six years Most of the time the eruption was kept under control, the patient requiring weekly treatments for new lesions in circumscribed areas Occasionally the disease would remain quiescent for a month or two, but most of the time new lesions were constantly developing The best that could be done in this case was to keep the patient comfortable and almost free of lesions.

The behavior of the disease under roentgenization as outlined in Case 3 is common. Such patients can be kept comfortable for periods

ranging from a few to many years. Case 4 represents a slightly different type where the results are better.

CASE 4.—Mrs. M. M., aged forty years. Duration of disease before roentgenization one year. The eruption was generalized and consisted of prefungoid lesions. The eruption disappeared in a few weeks under *x*-ray treatment and the patient remained asymptomatic for six months, when there was a rapid development of new lesions. This patient was under observation for eight years. She had a recurrence once or twice a year; the eruption always disappeared promptly when irradiated.

The next patient illustrates a common termination of even apparently favorable cases.

CASE 5.—Mr. G. W. The history of the eruption and its action when irradiated were similar to Case 4. At the end of four years prefungoid lesions developed faster than they could be made to disappear. A few months later *x* rays ceased to prove efficacious, the eruption became universal, tumors and enlargement of lymphatic glands developed and the patient became cachectic and died.

The remaining case reports illustrate the more unfavorable types.

CASE 6.—Mrs. J. A. C. The prefungoid stage had been present for five years. When first seen there was a generalized, prefungoid type of eruption with numerous tumors scattered over the body. The tumors ranged in size from a pea to a walnut. The patient had been given two or three *x*-ray treatments each week over a period of four months with considerable improvement. After four months of almost daily treatment the patient was free of skin manifestations but her general health was not very good. She returned in six months and stated that new lesions had been constantly developing and that they had not been influenced favorably by *x*-ray treatment received in another city. Carefully administered treatment kept the patient comfortable and fairly free of lesions for a few months, then *x* rays ceased to have any effect at all. The patient died two months after cessation of *x*-ray treatment.

CASE 7.—Mr. G. B., a Jewish woman, aged thirty-eight years, exhibited a generalized eruption consisting of pruritic, infiltrated plaques and numerous painful tumors ranging in size from a pea to a hickory nut. The duration of the disease was three years during which time the patient had suffered severely, especially with the itching. X rays had not been administered. Under the influence of irradiation itching was temporarily relieved and some of the lesions disappeared. In less than a year, however, *x* rays ceased to be of benefit and the patient died.

CASE 8.—Mr. A. C. D. This patient had had mild prefungoid symptoms for an indefinite period. He had never received *x*-ray treatment. Suddenly there developed numerous, very itchy plaques which were scattered generally over the body. The eruption disappeared under *x*-ray treatment. Three months later the patient exhibited markedly enlarged axillary, inguinal and cervical glands and a few infiltrated plaque. Both the adenitis and plaques regressed slowly under *x*-ray treatment. The patient was asymptomatic for four months. There was then a return of the adenitis and skin manifestations, the eruption consisting of infiltrated plaques and tumors and nodules. X rays were no longer efficacious and the patient succumbed.

CASE 9. —The patient was a man 65 years of age He presented a tumor on the dorsal surface of the left hand the size of an orange. The duration was three months There had been no antecedent eruption The histopathologic changes were those of mycosis fungoides (mycosis d'emblée). The lesion disappeared completely in two months subsequent to a single suberythema dose of filtered *x*-rays Within three months other tumors developed which failed to yield to irradiation and the patient died two years after the onset of the disease.

CASE 10.—A man of 68 He presented a universal erythroderma of three months' duration The histopathologic changes were those of mycosis fungoides ("homme rouge") He improved somewhat as a result of hospitalization, general medical care and topical remedies Later, his skin improved 75 per cent as a result of cautious general body irradiation over a period of a month. Apparently as a result of the irradiation his hemogram became alarmingly abnormal This was corrected by blood transfusions and iron During the following year his condition remained unchanged. That was a year ago; we have not heard from him since.

Possible Injurious Results of Irradiation.—In the early literature there are many reports of injurious and even fatal results of *x*-ray treatment. Such reports are now only of historic interest because in those days dosage was heavy. Those who are interested will find this early literature in detail in the last (third) edition of this book. Suffice it to say here that the lesions of mycosis fungoides are often exceedingly amenable to irradiation, so much so that rapid involution and absorption may lead to systemic toxemia, toxic rashes, septicemia and anaphylactic or protein shock. We no longer hear of such complications because of modern knowledge, judgment and technic. Any patient who receives general body irradiation, regardless of the disease or the technic, may have an undesirable drop in lymphocytes and other blood elements.

Pascher and Kanee have investigated this subject recently. They give the results of their own research and a review of the literature Their conclusions are as follows:

"Superficial roentgen rays, used in the treatment of generalized dermatoses, and administered three times a week to approximately one-quarter of the body surface, are harmful to the hematopoietic tissues of radiosensitive individuals.

"Such superficial radiation may be followed by leukopenia or by leukopenia and hypochromic anemia. Recovery may not be complete before four or five months

"The quantitative changes in the hemogram due to superficial radiation are similar to those following deep radiation.

"The combination of arsenotherapy with roentgen therapy may produce leukopenia, or leukopenia and hypochromic anemia, similar to the changes produced with roentgen rays alone."

Technic (X-rays).—Skin that is the site of a lesion of granuloma fungoides is likely to be more radiosensitive than is the surrounding normal skin. Therefore, large doses are not necessary. When there

are only a few scattered lesions, weekly treatments usually give excellent results As a rule, three or four doses of 75 r unfiltered will suffice to make any one lesion disappear

This technic is advised especially at the beginning of treatment, in order to avoid the possibility of toxemia Later, if the eruption is stubborn and localized, larger doses may be tried However to insist on the continuation of *x* ray treatment in cases that do not respond is poor policy

Often it is necessary to irradiate all or a greater part of the body surface For reasons given throughout this chapter it is advisable to begin with very small doses It is customary to divide the body into from three to six areas, depending upon the distribution of the eruption, and expose each area once weekly, and not more than one or two areas on any one day The dose at first is 38 r, unfiltered After two or three weeks the dose may be increased, if necessary, to 75 r

It is a good idea to make a differential white cell count about every two weeks If there is a substantial decrease of lymphocytes or if there are any signs of toxemia, irradiation should be discontinued temporarily

If the eruption becomes unyielding *x* ray treatment should be stopped and other methods tried After a few months' rest it is possible that irradiation will again prove efficacious

Lesions situated in the eyebrows or on the scalp may be treated in the same way as lesions on the glabrous skin, the only exception being that the dose is limited to a total of 225 r in one month When necessary it is permissible to administer larger doses to hairy regions regard less of the effect on the growth of hair

Filtration —As a rule filtered radiation is not necessary, except for large tumors because the lesions of granuloma fungoides yield readily to *x* rays of any quality With the exception of tumors, we have obtained exactly the same therapeutic results with both filtered and unfiltered radiation

Radium —Radium may be used advantageously for the treatment of lesions that are more or less inaccessible to *x*-rays—mouth, external auditory canal etc Also radium is suitable for circumscribed lesions on any part of the body Obviously, *x* rays are more suitable for extensive surfaces

If a lesion is not very thick, penetrating beta rays may be used, the very "soft' beta rays being eliminated by a thin screen of aluminum (0 1 or 0 2 mm) In the case of a tumor or a very thick patch only the gamma rays should be employed Dosage should of course approximate that for *x*-rays

LEUKEMIA CUTIS

The cutaneous manifestations of the different forms of leukemia lymphogranulomatosis, and the so called 'aleukemic and "pseudo-

leukemic" lymphoblastomas, to which the name "leukoses" has recently been applied, yield in a more or less capricious and inconstant manner to *x*-ray therapy. However, experience has demonstrated that isolated plaques and tumor masses may be quite radiosensitive. The lesions may regress with the same rapidity as those of mycosis fungoides, but as a general rule recurrences take place very quickly. Hence all treatment must necessarily be only palliative. Despite this, all patients should receive whatever benefit may be derived from *x*-ray therapy.

J W Jones and H S. Alden recently reported the case of a man, aged forty-five years, who for years suffered with a form of generalized erythroderma of the lymphoblastoma type, accompanied by severe itching. The blood picture was normal. He received *x*-ray treatment amounting to 75 r to the entire body each week for three months, followed by bi-weekly ultraviolet irradiations for six months, resulting in a complete disappearance of all symptoms. A few years ago, Wise presented a middle-aged woman before one of the dermatologic societies in New York, whose lymphatic leukemia was accompanied by an almost universal, dusky-red alteration in the skin, she complained of severe pruritus, the inflammation and itching vanished after only a few weekly doses of unfiltered *x*-rays, but recurrence took place one month after cessation of irradiation and *x*-ray therapy had to be repeated to control the itching and inflammation

The treatment of the various cutaneous manifestations of leukoses (lymphatic, myelogenous and monocytic leukemia, pseudoleukemia, lymphosarcoma, Hodgkin's disease and other leukoses) is necessarily only a relatively unimportant phase of therapy directed against the systemic disease itself. The majority of patients with skin lesions who are subjected to the modern methods of fairly intensive (deep) radiotherapy to combat the systemic symptoms (the entire reticulo-endothelial system) are freed of their superficial lesions in the course of such radiation therapy The term teleroentgen therapy has been given to this method

We have treated a number of cases of generalized leukemia cutis with *x*-rays There was some involution of lesions and some relief of the itching. Practically, the treatment was of very little value in these particular cases. In several patients with circumscribed eruptions thought to be due to leukemia the itching was arrested and the eruption disappeared

As indicated above, many physicians advocate the irradiation of the bones, spleen, and regions of lymphatic glands with filtered *x*-rays or gamma rays instead of or in addition to direct irradiation of the eruption in cases of mycosis fungoides, Hodgkin's disease of the skin and leukemia cutis For a complete literary review of this subject the reader is referred to the last (third) edition of this book and also to the book edited by Pohle.

LYMPHADENOSIS CUTIS

Wise's well known case of lymphogranulomatosis cutis (lymphadenosis cutis universalis, associated with generalized erythroderma and atrophy of the skin) was benefited by x-ray treatment the x-rays having been administered by Remer in Dr Fordyce's Clinic Itching was relieved and infiltrated plaques and boggy tumors disappeared Merlo and Arrillaga and Chaoul and Lange report excellent results with filtered x rays in a large number of severe cases

HODGKIN'S DISEASE

Hodgkin's disease is of interest to the dermatologist and he is often called in consultation to advise relative to diagnosis and treatment Furthermore in rare instances there are cutaneous manifestations in addition to the enlarged lymphatic glands The literature dealing with x ray and radium treatment of Hodgkin's disease is quite voluminous and all authors agree that in the majority of cases it is possible to effect a temporary clinical cure Recurrence is the rule but patients can be kept alive and in comfort for many years by the intelligent use of x rays or radium combined with proper general medical treatment

Alderson reports a case of Hodgkin's disease in which there were two large ulcers (Hodgkin's disease of the skin) which healed quickly when irradiated

Irradiation of the lymphatic glands demands filtered x-rays or heavily screened radium

RETICULO-ENDOTHELIAL DISEASES

In recent years studies directed toward the reticulo-endothelial system have thrown light on the interrelationships between disease processes in this system and the various forms of leukoses and lymphoblastomas In 1936 J Frank Fraser and Hans J Schwartz reported the case of a woman aged thirty-six years, with necropsy findings of reticulo endothelial disease showing features of mycosis fungoides Hodgkin's disease and reticular-cell lymphosarcoma the first sign being lesions of the skin with rapid coalescence and extension and involvement of the entire lymphatic system Necropsy revealed reticulo-endothelial lymphosarcoma with (1) involvement of the skin of the groins lower part of the abdomen vulva, inner aspects of the thighs axillæ breasts and left side of the neck (2) involvement of the lymph nodes and mesenteric omental and retroperitoneal tissues, and (3) metastatic lesions of the pleura, trachea, bronchi, spleen, colon, stomach and kidneys "There was convincing evidence that the neoplasm developed from the adventitial reticular cell of the terminal blood vessels of the sinuses of the mesenteric lymph nodes"

Although reports of radiation therapy in this type of morbid process are meager it may reasonably be assumed that systemic x-ray therapy

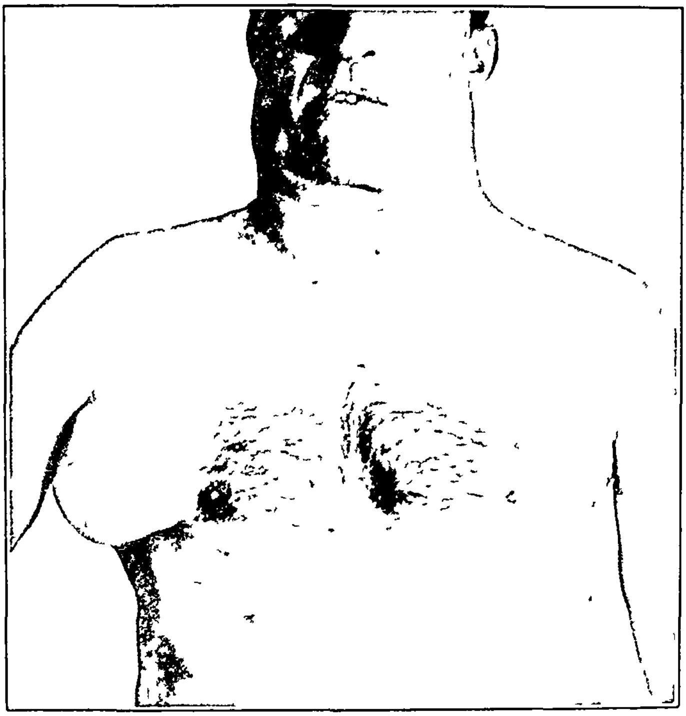

FIG. 205 —Hodgkin's disease, with very large glands of the axillæ and neck, before roentgenization

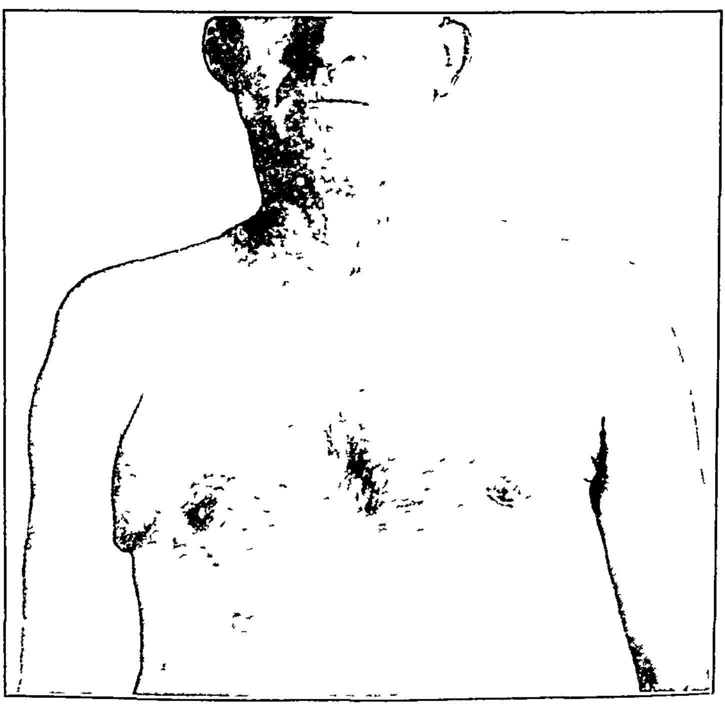

FIG 206 —Same patient shown in Fig 205, after weekly filtered treatment

as employed in the leukemias would prove at least to be palliative in its effects on diseases accompanied by evidences of involvement of the reticulo-endothelial system It may be said that the possible benefits of teleroentgen therapy should not be withheld in such cases since the prognosis as to life is in most patients quite hopeless X-ray therapy should be given a trial in an effort to relieve symptoms and to prolong life A literary review of this subject will be found in the last edition (third) of this book The reader is also referred to Pohle s book and other books dealing with the *x*-ray treatment of diseases other than those of the skin

BIBLIOGRAPHY

ALDERSON H E Cutaneous Metastases in Hodgkin Disease Jour Cutan Dis 35 481 1917

ALLEN C W in discussion on Sherwell A Case of Mycosis Fungoides Jour Cutan Dis 22 281 1904

——— Radiotherapy and Phototherapy Philadelphia Lea & Febiger 1904 pp 258 341

BISSERIÉ F The Treatment of Superficial Malignant Neoplasms by Radio-Therapy Arch Roentg Ray 11 142 1906–1907

CARRIER A E A Case of Mycosis Fungoides Treated by the X Ray Jour Cutan Dis 22 73 1904

CHAOUL H and LANGE K Ueber Lymphgranulomatose und ihre Behandlung mit Rontgenstrahlen München med Wchnschr 70 725 1923

DORE S E in discussion on Sequeira J H Discussion on Mycosis Fungoides Proc Roy Soc Med s Dermat 7 226 1914

FRASER J F and SCHWARTZ H J Neoplastic Disease of the Reticulo Endothelial System Arch Dermat and Syph 33 1 1936

GALLOWAY J in discussion on Sequeira J H Discussion on Mycosis Fungoides Proc Roy Soc Med s Dermat 7 213 1914

GEBER Quoted by Stelwagon H W Diseases of the Skin 9th ed Philadelphia W B Saunders Company 1923 p 953

HYDE J N MONTGOMERY F H and ORMSBY O S A Contribution to the Subject of Radiotherapy and Phototherapy in Carcinoma Tuberculosis and Other Diseases of the Skin Jour Am Med Assn 40 1 1903

JAMIESON W A Mycosis Fungoides and Its Treatment by the X Rays Brit Jour Dermat 15 1 1903

JONES J W and ALDEN H S Cutaneous Lymphoblastoma Some Remarks on Its Treatment South Med Jour 29 681 1936

KOBNER Quoted by Stelwagon H W Diseases of the Skin 9th ed Philadelphia W B Saunders Company 1923 p 953

LITTLE G in discussion on Sequeira J H Discussion on Mycosis Fungoides Proc Roy Soc Med s Dermat 7 223 1914

MCDONAGH J E R in discussion on Sequeira J H Discussion on Mycosis Fungoides Proc Roy Soc Med s Dermat 7 207 1914

MACLEOD J M H in discussion on Sequeira J H Discussion on Mycosis Fungoides Proc Roy Soc Med s Dermat 7 226 1914

MARSH J P A Case of Mycosis Fungoides Symptomatically Cured by Means of X Rays Am Jour Med Sci (n s) 126 314 1903

MERLO and ARRILLAGA Roentgenotherapy in Lymphogranulomatosis Rev Asoc méd argent 36 660 1923

MORRIS M in discussion on Sequeira J H Discussion on Mycosis Fungoides Proc Roy Soc Med s Dermat 7 205 1914

PASCHER F and KANEE B Reactions of the Hemopoietic System to Agents Used in the Treatment of Dermatoses 1 Effects of Low Voltage Roentgen Ray Arch Dermat and Syph 53 1 1946

PERNET G in discussion on Sequeira J H Discussion on Mycosis Fungoides Proc Roy Soc Med s Dermat 7 221 1914

POHLE E A Radiation Therapy in Medical Practice Leukemia Hodgkin s Granuloma and Allied Diseases Wisconsin Med Jour 34 632 1935

PUSEY, W. A., in discussion on Montgomery, F H The Present Status of Phototherapy, Am Med, 5, 982, 1903, also in Jour. Advanc Ther, 21, 642, 1903
———— Discussion on Phototherapy of Flat Nævi and the Treatment of Skin Diseases, Jour Advanc Ther, 21, 642, 1903
———— in discussion on Fordyce, J A, and Engman, M F Affections of the Mucous Membranes in Relation to Skin Diseases, Jour. Cutan Dis, 22, 436, 1904.
PUSEY, W A, and CALDWELL, E W Practical Application of Roentgen Rays in Therapeutics and Diagnosis, 2d ed, Philadelphia, W B Saunders Company, 1904, p 610
RIEHL Einen Fall von Mykosis fungoides, Fortschr a d Geb d. Rontgenstrahlen, 7, 41, 1903
SCHOLTZ, W Ueber den Einfluss der Rontgenstrahlen auf die Haut in gesundem und krankem Zustande, Arch f Dermat u Syph, 59, 87, 241, 421, 1902
SEQUEIRA, J H. Discussion on Mycosis Fungoides, Proc Roy Soc Med, s Dermat, 7, 190, 1914
STAINER A Case of Mycosis Fungoides, Brit Jour Dermat, 15, 137, 1903
STOWERS, J H, in discussion on Sequeira, J H Discussion on Mycosis Fungoides, Proc Roy Soc Med, s Dermat, 7, 216, 1914
WALKER, N, in discussion on Freund A Discussion on Radiography, "*X*"-Ray Treatment, the High-Frequency Method, and Light Treatment, Brit Med Jour, 2, 1319, 1902
WHITFIELD, A, in discussion on Sequeira, J H Discussion on Mycosis Fungoides, Proc Roy Soc Med, s Dermat, 7, 219, 1914
———— A Note on the Treatment of Sarcomatosis Cutis and Mycosis Fungoides by *X*-Rays, Lancet, 2, 328, 1927
WISE, F Lymphadenosis Cutis Universalis Associated with Generalized Erythrodermia and Atrophy of the Skin, Jour Cutan Dis, 35, 669, 1917

CHAPTER XXXV

DISEASES SUPPOSEDLY DUE DIRECTLY OR INDIRECTLY TO THE TUBERCLE BACILLUS

THE entities that will be discussed in this chapter are

1 Lupus Vulgaris
2 Lupus Erythematosus
3 Tuberculosis Orificialis
4 Tuberculosis Verrucosa Cutis
5 Scrofuloderma
6 Tuberculous Adenitis
7 Erythema Induratum
8 Sarcoid
9 Tuberculids
   - Papulonecrotic Tuberculid
   - Rosacea like Tuberculid
   - Lichen Scrofulosorum
   - Pernio
10 Granuloma Annulare

LUPUS VULGARIS

With the exception of hypertrichosis and cancer, lupus vulgaris was the first cutaneous disease to be treated with x rays Schiff is reported to have cured a case of this disease as early as 1896 The first men to treat this disease were In Germany and Austria, Schiff and Freund Hahn and Albers-Schonberg, in England Scholefield Hall-Edwards and Startin in France, Belot Gaston, Beclere, in the United States, Knox Pusey, Allen and Pfahler

After these early reports the literature on the subject became voluminous At first it was thought that a specific had been found for the disease A larger percentage of cases were cured then than now, because the early workers did not hesitate to effect a severe radiodermatitis in order to eradicate the disease Later when it was found that the sequelæ of radiodermatitis were serious x-ray treatment was administered in a more conservative manner and the effect on the disease was less spectacular

Today there is a difference of opinion relative to the efficacy of roentgen therapy in lupus vulgaris This difference of opinion is occasioned partly by a lack of appreciation of the effect of x-rays on different clinical types of the disease

There are a great many adjectives used to describe the many varia-

tions in the clinical appearance of lupus vulgaris For convenience we may combine these many clinical varieties into the following types.

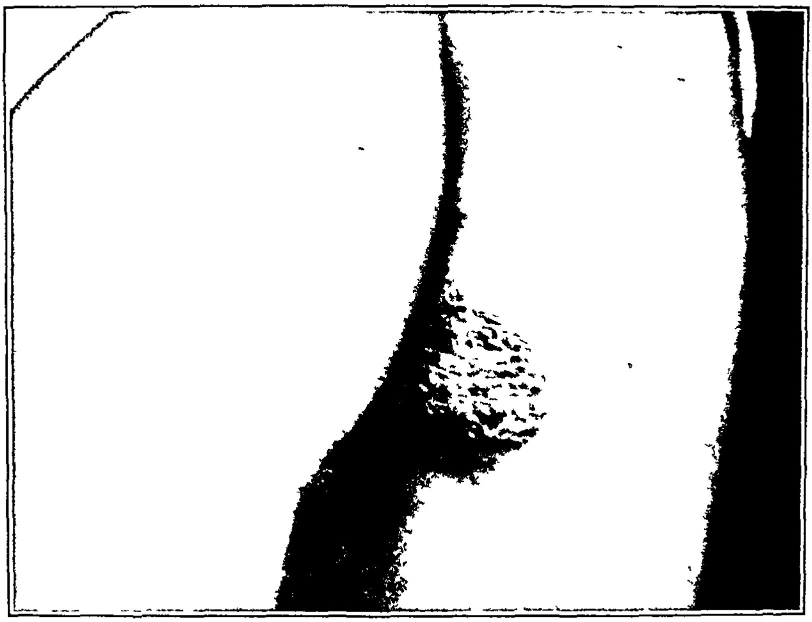

Fig 207.—Hypertrophic lupus vulgaris before x-ray treatment The scar is the result of the excision of a former lesion

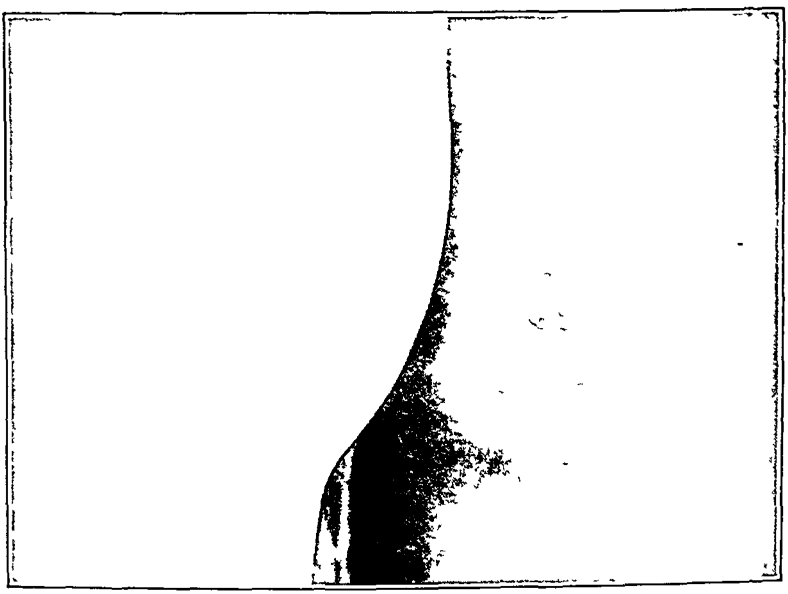

Fig 208 —Same patient shown in Fig 207, after one suberythema, unfiltered x-ray treatment No recurrence in twelve years

1. Atrophic type
2. Hypertrophic type
3. Ulcerative type
4. Multiple disseminated type.
5. Miscellaneous types.

Atrophic Lupus Vulgaris.—In this type the skin becomes atrophic and the affected area is studded with deep seated pinhead- to lentil-sized nodules of a yellowish brown color (apple-jelly nodules). The nodules may project above the niveau of the skin, but, as a rule the surface of the affected area is even, although it may be scaly. We have found the atrophic type of lupus vulgaris exceedingly unyielding to both x-rays and radium and, as a rule, it is necessary, in order to effect a cure, to support such treatment with tuberculin therapy or to destroy the individual nodules by electrosurgery.

In early cases when the lesions are small, and before sclerosis and fibrosis have occurred, or in instances where the nodules are larger and nearer the surface, the results of roentgen therapy are better. The younger the lesion, the smaller the lesion and the greater the rapidity of evolution, the greater will be the effect of the x-ray treatment. Such eruptions may disappear as a result of two or three suberythema treatments. Older eruptions associated with atrophy and deep-seated nodules will, as a rule, fail to yield to safe dosage.

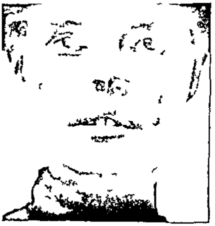

Fig. 209 Fig. 210

Fig. 209.—Lupus vulgaris of the hypertrophic type with involvement of the mucosa. (Courtesy of Dr. J. F. Schamberg.)

Fig. 210.—Same patient shown in Fig. 209 after x-ray treatment. (Courtesy of Dr. J. F. Schamberg.)

Hypertrophic Lupus Vulgaris.—Here the nodules are larger (lentil to split pea size), project above the surface of the skin and are coalesced. The coalesced nodules and hyperplastic skin together form elevated firm but not hard brownish red plaques and tumors of various sizes. Small lesions of this type can often be permanently cured with one suberythema treatment. Larger and older lesions are more stubborn but, as a rule, this type of lupus vulgaris yields more readily than does the atrophic type of the disease, and recurrences are less common.

Ulcerative Lupus Vulgaris.—Ulceration may occur in either the atrophic or the hypertrophic type. Ulcers under x-ray treatment,

usually heal much more rapidly than the neighboring nodules resolve. The results of roentgen therapy in ulcerative lupus vulgaris are often satisfactory, especially when the disease involves the face and the nasal and buccal mucosæ. Unfortunately recurrences are common. During treatment the ulcers should be kept clean and free from crusts, and individual nodules destroyed by other methods of treatment

Fig 211 —Lupus vulgaris of hypertrophic or verrucous type before treatment

Fig 212 —Same patient shown in Fig 211, after two suberythema *x*-ray treatments Numerous nodules still remain The case is now one of the atrophic type and for a good result other therapeutic methods must be used

Multiple Disseminated Lupus Vulgaris.—The individual scattered nodules of this type have undergone rapid involution in the few cases treated by us.

Miscellaneous Types —The serpiginous type of lupus vulgaris is very rebellious if the nodules are small and deeply embedded If the nodules are larger and more superficial the disease is less stubborn If ulcerated the ulcers will usually heal under the influence of the x-rays

The early literature contains reports of good results obtained in lupus tumidus We have treated only one example of this type After several months of filtered treatment there was definite improvement but the patient was not cured

FIG 213 —Lupus vulgaris involving the nasal mucosa before treatment It was necessary for the patient to breathe through the mouth

FIG 214 —Same patient shown in Fig 213 after several subintensive treatment The pinched condition of the nose is the typical result of lupus

Comparative Value of Roentgen Treatment —Roentgen therapy has not replaced phototherapy in point of efficacy The Finsen treatment has given better results than have thus far been obtained with either x rays or radium Forchammer in a statistical report based on 1200 unselected cases of lupus vulgaris treated at the Finsen Light Institute between 1896 and 1906, gives the following results of the treatment Cures, 60 per cent under treatment 18 per cent treatment discontinued, 11 per cent, dead, 11 per cent Of the total cured (721) 33 had been free from recurrence for ten years or more, 289 for from five to ten years 306 for from two to five years, and 93 for less than two years In a further study the subjects are divided into initial cases and inveterate cases In the initial cases 76 per cent were cured, while in the inveterate cases 51 per cent were cured (Ormsby) The authors have not been able to obtain such good results with roentgen

therapy, nor have they encountered roentgen or radium statistics that show results in unselected cases of lupus vulgaris that are the equal to those quoted above. For various reasons the Finsen treatment has been found impracticable in this country and substitute methods, such as the water-cooled and air-cooled quartz lamps, have, in most hands, proved disappointing. The Finsen treatment not only cures a high percentage of cases but it does so without producing injury or sequelæ

Small lesions, suitably situated, can be excised Surgical methods, however, are necessarily limited to selected cases The same is true of tuberculin therapy, refrigeration, electrosurgery and other methods of treatment

FIG 215

FIG 216

FIG 215 —Lupus vulgaris clinically resembling lupus erythematosus, before treatment

FIG 216 —Same patient shown in Fig 215 after x-ray treatment Depigmentation is due to the disease

Combined Treatment.—Irradiation may be combined with phototherapy, but it is not wise to apply reaction doses of ultraviolet rays and *x*-rays or radium at the same time The two methods may alternate or one method may follow the other. We have tried this scheme in obstinate cases, but the results have not been encouraging. The use of tuberculin, electrosurgery and diet have proved of distinct value when combined with irradiation. It is of the utmost importance, in the ulcerative type to provide drainage and to keep the ulcers clean and free from crusts A small amount of ultraviolet rays may be advantageously combined with irradiation in the treatment of open ulcers. Refrigeration and caustic and irritating ointments are contraindicated during irradiation.

Lupus Vulgaris, X-rays and Cancer—Stumpke encountered 2 cases of lupus vulgaris that had received x-ray treatment for many months. Epithelioma developed in the scar tissue in both patients. Stumpke calls attention to the fact that he has seen 150 cases of lupus vulgaris, and he never noted epithelioma in any case that had not received x-ray treatment. The 2 patients with epithelioma also showed x-ray sequelæ.

FIG. 217.—Lupus vulgaris cured with x rays thirty years ago. Patient now shows epithelioma developing in the lupus scar. (Dr. Fred Wise's patient.)

MacLeod reports a patient with lupus vulgaris who presented both x-ray sequelæ and epithelioma. Gaucher and others have seen similar cases. We have seen 3 cases where epithelioma developed in a scar that was caused partly by the disease and partly by a severe radiodermatitis.

It is a well known fact that epithelioma occurs as a sequel in lupus vulgaris that has not received x-ray treatment. The epithelioma is usually of the prickle cell type. Ormsby states that this sequela occurs in from 2 to 4 per cent of the cases. Lieberthal, Zeisler, Pusey, Hyde and others have seen epithelioma develop as a sequel to lupus vulgaris in patients who had not received x-ray treatment. This subject is discussed also in the chapter dealing with cancer and the precanceroses.

There is no proof that irradiation increases the natural tendency of epithelioma to develop as a sequel to lupus vulgaris unless irradiation has been pushed to the point of producing the so-called x-ray skin. X-ray sequelæ are likely to be the forerunners of cancer, whether such sequelæ are or are not associated with lupus vulgaris. Disregarding the cases of lupus vulgaris in which epithelioma develops in an x-ray sequela, there is no evidence in the literature to show that epithelioma as a sequel to lupus vulgaris is more common today than before the advent of roentgen therapy.

Lupus vulgaris may cause considerable disfigurement. The usual sequelæ are scars and atrophy. It not infrequently happens that irradiation is blamed for these sequelæ.

Technic.—It is our experience that large monthly (suberythema) doses are more efficacious in lupus vulgaris than are weekly treatments. The routine is to administer about 225 r. unfiltered, every four weeks. The dose will vary with the location and size of the affected area and the age of the patient. The dose will range from 150 r. in children, to 250 or 275 r. in adults and aged individuals.

While the patient will recover more quickly if the dose is sufficient to effect a sharp reaction, it is preferable to avoid even slight reactions. In many cases of lupus vulgaris it is necessary to continue the treatment over several months and if each treatment, or if several of the treatments result in even a first-degree reaction, the ultimate outcome may be serious *x*-ray sequelæ. The aim should be, therefore, to administer each month as much as the skin will tolerate without visibly reacting. It is difficult to determine just how long such treatment may be continued without serious injury. In obstinate cases it seems advisable to limit the number of monthly treatments to three or four. The skin should be carefully inspected at each treatment for evidence of injury. If an eruption has not disappeared after this amount of treatment it is advisable to discontinue irradiation and depend upon other methods of treatment. Not infrequently, after several treatments the eruption, with the exception of a few nodules, will disappear. It is unwise to depend upon irradiation to cause the involution of these remaining nodules. They can be quickly destroyed by other methods of treatment.

Filtration is often indicated in this disease. Especially is this true when the disease involves the mucosa of the nose, mouth and throat. In such instances with filtered radiation, the lesions of the mucous membranes may disappear under the influence of radiation applied to the cutaneous eruption on the face. Pfahler and we have reported clinical cures accomplished in this manner. Whether or not filtration is advisable in all cases of lupus vulgaris is an open question—it cannot be answered at the present writing.

Lesions of lupus vulgaris are of various sizes and occur in many parts of the body. The method of handling lesions of different size, shape and position will be found in the Chapter on General Therapeutic Considerations. It is advisable not to shield too close to the lesion, as the disease is likely to extend beyond the visible margin.

Radium.—A review of the work done by Wickham and Degrais, Simpson, Newcomet and others, together with personal experience, shows that the results obtained with radium in the treatment of lupus vulgaris are about the same as those associated with the use of the *x*-rays. The best results have followed conservative irradiation combined with other methods of treatment.

In some small, superficial lesions of lupus vulgaris the beta rays have seemed more efficacious than have either *x*-rays or gamma rays. The "soft" beta rays should be eliminated by a screen of 0.1 mm.

aluminum Good results have been reported with grenz rays and with contact x-ray tubes

Radium is especially indicated when the lesions are situated in inaccessible locations—nasal and buccal cavities, throat and conjunctivæ

LUPUS ERYTHEMATOSUS

Schiff and Freund were probably the first to treat lupus erythematosus with the x-rays (1898) Their report was soon followed by those of many roentgenologists and dermatologists—Startin Lee, Béclère Belot Hall-Edwards Pusey and others

At first the results were promising and were superior to those obtained today, that is the immediate results The early workers did not hesitate to produce severe reactions and the immediate therapeutic effect on the disease was often very striking Later when it was ascertained that the brilliant result was but temporary, and that undesirable sequelæ often followed radiodermatitis, the treatment was applied more cautiously and the effect on the disease was less spectacular

A review of the literature for the last thirty years shows that the x-rays have been used less and less in the treatment of the disease Zeisler Hartzell Montgomery, Winfield and many others record good temporary results without the production of radiodermatitis Fordyce Robinson Bronson and others reported cases that were made worse, or failed to improve or improved but little as a result of the treatment

Value of Roentgen Therapy—The consensus among dermatologists today is that roentgen therapy is of little value in the treatment of lupus erythematosus and it is seldom used Its value is certainly less than that of refrigeration gold sodium thiosulphate bismuth mapharsen and other methods Nevertheless, the x-rays if properly used in well-selected cases will occasionally cause involution of lesions that have resisted other methods of treatment

Types of Lupus Erythematosus—It is important for the roentgenologist to know that lupus erythematosus occurs in two general types—discoid or chronic and disseminated or acute It is well to remember also that the course of the disease is very uncertain Discoid lesions are likely to persist for many years or they may undergo spontaneous involution only to recur subsequently The disseminate type often disappears spontaneously, or as a result of local applications, in a few weeks or months Rarely it persists and spreads and the patient dies of tuberculosis, more often of nephritis streptococcic infections and asthenia (Jadassohn, Baer and others)

Technic—For the disseminate type especially when associated with acute inflammatory symptoms the treatment should be weekly with doses from 38 to 75 r unfiltered The discoid lesions may be given suberythema doses once monthly for from one to three treatments

It is advisable to avoid even a first-degree reaction. A mild x-ray reaction is likely to cause the disease to spread and may add to the atrophy and telangiectasia occasioned by the disease. It is well to remember that, while the x-rays may cause involution of a lesion of

FIG 218 —Lupus erythematosus

lupus erythematosus, they exert little if any effect on the future course of the disease For this reason it is not justifiable to push the treatment to the point of visible cutaneous injury Furthermore, it is not advisable to persist in the roentgen treatment of a stubborn lesion If the lesion does not disappear as a result of three or four months of

FIG 219 —Same patient shown in Fig 218, after radium treatment

treatment, experience has shown that it will not be favorably influenced by a continuation of such treatment

The nose is a favorite site for lesions of this disease. Details relative to the method of applying x-rays to the nose and to convex and

concave surfaces, to lesions of various sizes and shapes to lesions on the eyelids and other locations, etc, will be found in the Chapter on General Therapeutic Considerations

There is a difference of opinion relative to the advisability of confining the radiation strictly to the lesion or of including a small area of normal skin around the lesion in the field of radiation With doses sufficient to effect a first-degree reaction the authors have seen peripheral spreading of the lesion when the radiation has been confined to the lesion and also when the normal skin adjacent to the lesion has been irradiated While a first degree reaction will often have a beneficial effect on discoid lesions the converse is also true Quantities that do not effect a reaction rarely if ever make the lesion worse, although such treatment may accomplish little if any good Scalp lesions may be treated with a full epilating dose (300 r) For details relative to the treatment of scalp lesions see chapter on Psoriasis and chapter on Tinea Capitis

Comparative experiments with filtered and unfiltered radiation have yielded similar results Apparently there is nothing to be gained by filtration in the roentgen treatment of this disease

Goeckerman reports on 17 cases of discoid and disseminate lupus erythematosus in which he applied filtered *x* rays to the gland-bearing regions of the body In most of the cases the result was encouraging We tried this treatment on one patient applying the radiation to the mediastinal region front and back After the second suberythema dose (monthly intervals) lupus developed in the areas irradiated Wise (verbal) reports a similar result with one erythema dose of ultraviolet radiation and Goeckerman encountered a phenomenon of this kind with *x* rays He believes that the good results are due to protein shock

Sequelæ —Lupus erythematosus causes atrophy, wrinkling telangiectasia and permanent alopecia The picture at times is suggestive of *x*-ray sequelæ In cases that have received roentgen ray treatment it is often impossible to decide how much of the disfigurement is due to the disease and how much is due to the treatment Epithelioma occurring in patches of lupus erythematosus or in the atrophic skin following involution of lesions in cases that have not been irradiated have been reported by Pringle Dyer and others We have encountered several such cases

Combined Treatment —When applying radiation to acute lupus erythematosus it is advantageous also to apply such soothing remedies as zinc oxide ointment and calamine lotion In the chronic type when stimulating and caustic remedies (resorcin, lotio alba liquor potassæ etc) are indicated it is advisable not to combine the use of such remedies with irradiation unless the *x* ray dose is very small Ultraviolet rays and especially refrigeration, should not be used during *x* ray treatment

In the past few years intravenous injections of gold and sodium thiosulphate and intramuscular injections of bismuth have given such excellent results in cases of lupus erythematosus that other methods of treatment have been neglected

Radium.—The results obtained with the beta rays of radium are perhaps better than those obtained with either *x*-rays or gamma rays. Wickham and Degrais, and Clark, with unfiltered beta radiation sufficient in amount to provoke a sharp reaction, have obtained good temporary results in the discoid type. They advise sharp but not severe reactions and also that the skin in the immediate neighborhood of the lesion be included in the treatment. We advise against such treatment Simpson, Knox, Newcomet and others have testified to the favorable results sometimes obtained with radium in lupus erythematosus

FIG 220 —Tuberculosis orificialis before treatment

FIG 221 —Same patient shown in Fig 220, after one intensive treatment and one subintensive treatment with unfiltered *x*-rays

As a result of comparative clinical experimentation with *x*-rays and radium in this disease, we think that radium is the better agent There is no apparent difference in the effect on the disease of *x*-rays and gamma rays, but there is a difference with beta rays, especially those of "medium" quality The best results have been obtained with an applicator filtered with 0 1 mm aluminum Favorable results have been reported with grenz rays and with "soft" *x*-rays administered with the tube in contact with the skin

The effect on the disease is greatest when the dose is sufficient to produce a sharp reaction. A reaction resulting from "soft" beta rays, even when severe, heals quickly and is less likely to be followed by telangiectasia, atrophy and keratoses than are reactions subsequent to applications of *x*-rays or gamma rays However, such sequelæ do occur, therefore it is preferable to avoid reactions But regardless of technic, most cases of lupus erythematosus fail to improve under radium treatment

TUBERCULOSIS ORIFICIALIS

Tuberculosis of the orifices may be primary, but it is usually secondary to lupus vulgaris or to tuberculosis of the lungs, kidneys, etc. Both radium and x-rays are of value in the treatment of tuberculous ulcerations of the mucosae. When the mucous membrane involvement constitutes an extension from lupus vulgaris of the skin these agents are often efficacious. Primary tuberculous ulcers of the conjunctiva, buccal mucosa, glans penis, etc., may at times be cured with either agent. Ulcers of the tongue, throat, penis and anal region secondary to tuberculosis of the internal organs are more stubborn.

In general, radium is to be preferred to x-rays in the treatment of tuberculous ulcers of the mucosa, principally because the lesions are inaccessible to x-ray treatment.

Fig. 222.—A small lesion of tuberculosis verrucosa cutis before treatment.

Fig. 223.—Same patient shown in Fig. 222 after one x-ray treatment.

TUBERCULOSIS VERRUCOSA CUTIS

True examples of tuberculosis verrucosa cutis are likely to be found resistant to both x-rays and radium. We have cured a number of cases of verruca necrogenica with one x-ray treatment. Such favorable results are not often obtained, however, in well-developed verrucous tuberculosis. The result will depend largely upon the extent of the involved surface and the thickness of the epidermis, especially the horny layer. All cases so far treated by us have been cured in from three to eight monthly treatments. If the hyperkeratosis is considerable the lesion is closely shielded and a dose of filtered x-rays (400 r) is administered. The hole in the lead shield is then enlarged so that $\frac{1}{2}$ inch of normal skin around the lesion is included in the field of radiation. Another dose of similar amount is applied. The lesion will

have received a dose of 800 r while the apparently normal skin will have received half the amount, thus the normal skin will not be injured. In some instances it is permissible to administer as much as 1100 r or even 1650 r, filtered through 3 mm of aluminum, to the lesion itself, especially in the case of very small lesions. The dose will depend upon the thickness of the horny layer and the size of the lesion. The treatments are given as a routine at intervals of one month.

FIG 224 —Tuberculosis verrucosa cutis before *x*-ray treatment

There are few references in the literature referring to the use of radium in this disease, and there has been no personal experience Simpson, Wickham and Degrais and a few others have obtained good results. There is no reason why radium should not have exactly the same effect as the *x*-rays. In using radium the beta rays should be eliminated by suitable filtration.

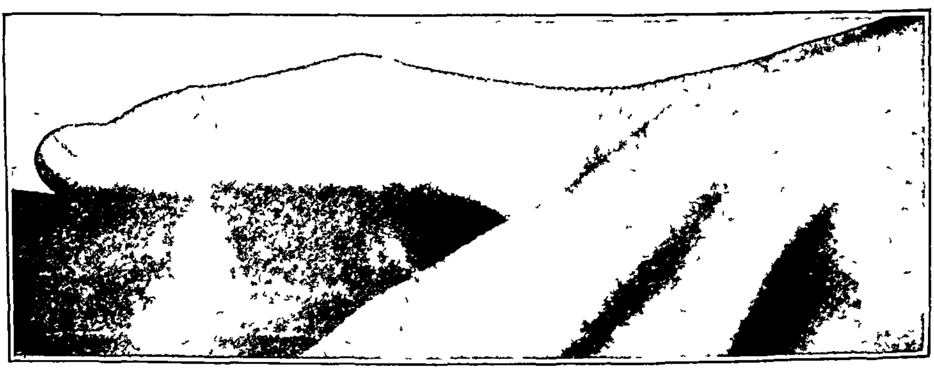

FIG 225 —Same as Fig 224 after several suberythema doses of *x*-rays

SCROFULODERMA.

The term scrofuloderma implies ulceration of the skin and subcutaneous tissues associated with underlying, suppurating tuberculous glands, tuberculous osteomyelitis, or other deep-seated tuberculous foci. For convenience we can also include superficial tuberculous

ulcers that do not fit into any clinical entity and which are often spoken of as ulcerative tuberculosis cutis Often, these superficial ulcers heal when irradiated occasionally they are stubborn

Ulcers and sinuses associated with underlying tuberculous foci may respond well to irradiation, especially if the treatment is directed at the deep foci (filtered radiation) and good drainage is established We have seen clinical cures in cases of suppurating tuberculous adenitis and tuberculous osteomyelitis with involvement of the underlying tissues and in the so-called scrofulous gumma after the contents of the abscess have been evacuated Furthermore, the percentage of recurrences has been small In such conditions it is advisable to prescribe internal medication, dieting and hygiene, and in many instances surgical aid may be required

The principal technical requirement is to apply lethal doses to the deep foci without injury to the overlying tissue This is done by distance filtration and crossfire, technical questions that are discussed in detail in previous chapters

Suberythema doses at monthly intervals are indicated, cross-fire treatment should be given whenever possible radium and x-rays appear to give the same results

Bowen Ratera Nadler, Denks and others report interesting examples of scrofuloderma associated with tuberculous adenitis that were cured with x rays Denks report includes scrofuloderma associated with various types of surgical tuberculosis Of 325 cases there were 43 fungoid lesions connected with the large articulations Of these, 35 per cent were clinically cured 25 per cent improved 15 per cent did not improve and 25 per cent failed to continue the treatment There were 101 cases associated with tuberculous adenitis of which 82 were cured Lesions connected with small articulations showed a percentage of cures of 84 There were 67 cases of large fistulae, half of which were cured, and 54 small fistulae 60 per cent of which were cured Williams was one of the first to recognize the value of roentgen therapy in scrofuloderma and tuberculous adenitis

TUBERCULOUS ADENITIS

Tuberculous adenitis is not a dermatosis The disease is of interest to the dermatologist because it may be associated with the various tuberculous conditions of the skin and also because of the disfiguring scars often caused by the disease and by the treatment especially in tuberculous adenitis of the cervical region

Roentgen therapy has given good results in this disease Our experience is limited to the treatment of 30 cases of cervical tuberculous adenitis Twelve cases were clinically cured In 3 patients the glands remained the same size but a roentgenogram showed them to be calcified In 10 cases the glands were reduced in size but they could be palpated and were not calcified Five patients

failed to remain under treatment. The cured cases were children or adolescents.

Tuberculous adenitis, together with scrofuloderma, was one of the first conditions to be treated successfully with the x-rays, the earliest

FIG. 226.—Tuberculous adenitis before treatment. (Weil.)

FIG. 227.—Same patient shown in Fig. 226, after treatment. (Weil.)

reports having been made in this country (Williams, Rodman and Pfahler, Varney and Pusey). The literature on this subject later became voluminous. Illustrated, technical articles have been published by Boggs, Weil, Leonard, Knox, Strunsky, Berry, Kaplan, Rosh and Quinn, and many others.

FIG. 228.—Tuberculous adenitis before treatment. (Weil.)

FIG. 229.—Same patient shown in Fig. 228 after treatment. (Weil.)

Tuberculous adenitis is a surgical disease and, also, it is one that requires general medical supervision. Therefore it is advisable that the roentgenologist work in collaboration with surgeons, internists,

pediatricians, laryngologists, etc, when attempting to select cases for roentgenization. The results of roentgen therapy have been so good that if there is no contraindication to such treatment in the minds of internists or surgeons, the x rays or gamma rays along with general medical measures, should be given a trial in order to avoid the scarring *and shock associated with surgical intervention*.

Technic — We are dealing with a deep-seated condition and one that requires filtered radiation. Furthermore, as tuberculous adenitis is usually situated in the cervical region great care should be exercised to avoid cutaneous injury. Most of these patients are young (adolescents, children and infants) and the skin has a low tolerance. Even in adults the skin of the anterior and lateral surfaces of the neck is more sensitive to radiation than is that of other parts of the body. Telangiectasia or atrophy or scarring on the neck of a girl is extremely unfortunate and has marred many excellent therapeutic results that have been obtained in this disease.

It is possible to obtain quick results with large doses, but such a procedure is rarely justified. It is preferable to administer small amounts at monthly intervals for eight, ten or twelve months and to avoid even a mild reaction of the first degree. With 3 mm of aluminum as a filter, the first dose in infants and children should not exceed 180 r. In adults it may be 400 r. The doses are cautiously increased, the skin being carefully inspected at each visit for signs of saturation. These signs may be detected by a too rapid and pronounced reaction to friction and hot water on the part of the skin. We have seldom been able to give to the lateral surface of the neck in adults more than 550 r without evoking a slight erythema. It is admitted that these doses are small, but when it is remembered that a single well marked reaction of the first degree may possibly be followed by *telangiectasia it becomes obvious that such extreme* caution is advisable. Many operators prefer to administer one-half the skin tolerance dose every second week. This scheme has the possible advantage of a larger total dose with no greater injury to the skin. When administering long continued treatment to the neck and mediastinum it is advisable to avoid, as far as possible, irradiating the thyroid and thymus glands, especially in very young subjects. In some situations *such as the axillæ, extremities and mediastinum, it is* possible to use the cross fire method.

Radium — Radium has not yet been employed as extensively in the treatment of tuberculous adenitis as have the x rays. The literature contains comparatively few reports of such treatment. The affected glands are likely to be distributed over a rather large area, and unless the operator has considerable radium or radon, he is likely to prefer the x rays. *The therapeutic results appear to be the same with both* agents. Molyneux in 1914 reported the successful treatment of 30 cases of cervical tuberculous adenitis with radium. Many of the patients were kept under observation for a number of years. The

cure was complete and apparently permanent. There were no radium sequelæ Simpson reports excellent results.

When using radium it is customary to employ radium element tubes containing 50 mg of element or radon rubes of the same strength. One tube should be used for each square inch of surface. The distance is 1 inch The filter is 0 5 mm. silver, 1 mm. brass and 1 mm. aluminum, The exposure is two to four hours. A second treatment is not given until improvement ceases. It should not be given in less than a month or two

ERYTHEMA INDURATUM.

(Bazin's Disease.)

Schultz quotes and agrees with Ehrmann who considers that roentgenization is the best treatment for erythema induratum. We have found treatment useful, but experience does not permit accord with Ehrmann. Ulcerative lesions will not infrequently heal under the influence of one or two suberythema filtered treatments. Deeper, nonulcerative nodules often require several such treatments. Recurrence of the disease is common. White, Bowen and others have reported good results but admit recurrences.

It is difficult to determine the true value of irradiation in this disease The lesions usually disappear spontaneously in a few months, especially in patients who can rest and who receive proper advice relative to hygiene and general medical treatment. There is no denying the fact, however, that persistent lesions often yield to irradiation

The technic consists of applying suberythema filtered radiation to the individual lesions once a month

Heavily filtered gamma rays are as efficacious as are x-rays. It is advisable always to give the patient the advantage of general medical treatment

SARCOID.

We have obtained some satisfactory results with both x-rays and radium in the treatment of the superficial and deep types of sarcoid—Boeck type and Darier-Roussy type—the lesions disappearing in from one to three treatments The results, however, have been better in the Darier-Roussy type Like erythema induratum, to which it is closely allied, the lesions of sarcoid are likely to be evanescent, and it will require observation over a period of many years to determine the value of x-rays and radium in the treatment of this uncommon condition Darier reports good results with x-rays, his first report having been made in 1904 H. Fox failed to cure with x-rays an extensive case of sarcoid in which there were numerous large and rather deep-seated nodules. There was some improvement, but it was necessary to resort to other methods of treatment in order to effect a cure. Zeisler treated

a generalized eruption of Boeck's sarcoid with both x-rays and radium The result was slight involution of the lesions

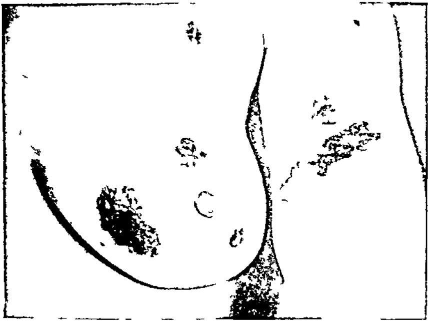

Fig 230 —Sarcoid of Darier Roussy type before roentgenization

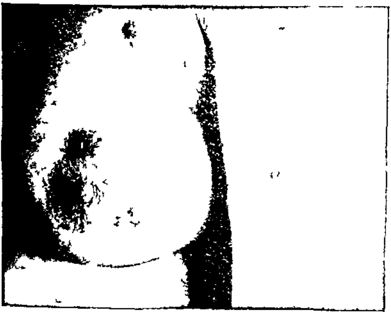

Fig 231 —Same patient shown in Fig 230 after x ray treatment

Boeck's sarcoid occurs in two general clinical types In one type the lesions consist of rather superficial plaques In the other type the lesions consist of various sized nodules situated deep in the true

skin. Good results may be sometimes obtained in the superficial cases with unfiltered *x*-rays or with gamma rays. The deeper and larger lesions should be treated with filtered *x*-rays or gamma rays. The same is true of the subcutaneous sarcoid of Darier-Roussy and allied conditions, such as tuberculosis of the hypoderm described by Wende. The dose is suberythema, administered about once a month.

Sarcoid, especially Boeck's type, shows a predilection for the face. In this location, especially, it is advisable not to effect an erythema The disease itself is likely to be followed by atrophy and the disfigurement will be worse if telangiectasia and additional atrophy is occasioned by the treatment. It is preferable, therefore, to administer several suberythema doses rather than to attempt a cure in one treatment.

THE TUBERCULIDS.

Ormsby has found *x*-rays of service in papulo-necrotic tuberculid. Knowles and Ketron treated cases of "acnitis" with *x*-rays and noted involution of the eruption Bronson obtained a similar result in a case of "folliclis"

The tuberculids are widespread, evanescent, recurring eruptions Recurrences cannot or at least have not been prevented by roentgen therapy The natural course of the eruption apparently can be shortened by the administration of weekly unfiltered treatment

We have tried fractional unfiltered *x*-rays for the rosacea-like tuberculid of Lewandowsky with disappointing results

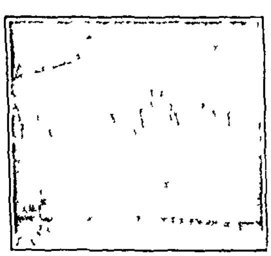

FIG 232 —Granuloma annulare before treatment

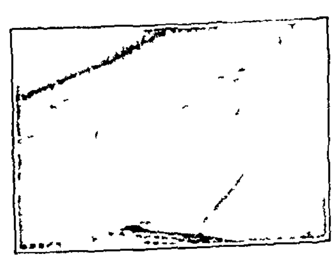

FIG 233 —Same as Fig 232, after one *x*-ray treatment

Lichen Scrofulosorum.—In recent years this disease has been removed from the tuberculids and placed among the cutaneous tuberculoses. We have treated 2 cases of this disease with unfiltered radiation In both instances the eruption disappeared after irradiation had been continued for four months (75 r weekly) The involution of the eruption may have been spontaneous or it may have been due to improved general hygiene The disease in both patients had been present for several months before *x*-ray treatment was instituted. No topical applications were made

We have found the *x*-rays to be efficacious in the treatment of granuloma annulare. Many cases of this disease were treated. In no instance was it necessary to give more than two suberythema treat-

FIG 236 —Granuloma annulare before radium treatment

FIG 237 —Same as Fig 236 after one suberythema radium treatment Glazed applicator filtered with 0 1 mm aluminum

ments and usually the lesions underwent involution subsequent to a single application of the radiation. The lesions are shielded closely and each lesion is given a suberythema dose If involution is not complete in a month a second application is made. Papules and small nodules are treated with unfiltered radiation, large nodules are treated

with filtered radiation The lesions do not recur but new ones may develop

Hartzell, White, Ormsby Goldenberg and Chargin and others have reported good results with x rays Both gamma rays and beta rays are efficacious

BIBLIOGRAPHY

ALLEN C W Radiotherapy and Phototherapy Philadelphia Lea & Febiger 1904 p 248

ALBERT-WEIL E La radiothérapie des adénoïdites tuberculeuses périphériques Paris méd 6 260 1916 Abstr Am J Roentgenol 4 449 1917

BECLÈRE Le dosage en radiothérapie et son tracé graphique Bull Soc franç de dermat et syph 15 117 1904

BELOT J Radiotherapy in Skin Disease New York Rebman Company 1905 p 314

BERRY M X ray Treatment of Tuberculous Gland Brit Jour Tuberc 15 13 1921

BOWEN J T [X ray Treatment at Boston General Hospital During the Past Year] Jour Cutan Dis 21 370 1903

BRONSON E B A Case of Lupus Erythematosus Treated by the X ray Jour Cutan Dis 21 101 1903

DARIER J Die cutanen und subcutanen Sarkoide Monatsh f prakt Dermat 50 419 1910

DARIER J and ROUSSY Un cas de tumeurs bénignes multiples (sarcoides sous cutanées ou tuberculides nodulaires hypodermiques) Ann de dermat et syph 4 ser 5 144 1904

DEYKS H Zur Rontgenbehandlung der chirurgischen Tuberkulosen Deut med Wchnschr 41 509 1915 Abstract Am Jour Roentgenol 2 922 1915

DYER I A Case of Lupus Erythematosus of the Face and Body With Superinduced Epithelomata of the Face Texas Med Jour 8 178 1892-1893

FELDSTEIN S L The Treatment of Tuberculous Glands of the Neck by the X ray New York Med Jour 85 20 1907

FORCHHAMMER H *Die Bekämpfung des Lupus vulgaris in Dänemark 1896–1911* in Verhandl d 3 Sitz d Lupus Ausschlusses d deutsch Zentral Kommittee 1911 Abstract Brit Jour Dermat 23 338 1911

FORDYCE J A [Comment on Bronson s Case] Jour Cutan Dis 21 101 1903

FOX H Case for Diagnosis (Sarcoid or Mycosis Fungoides?) Jour Cutan Dis 35 *180 1917*

FRITSCH Roentgentherapy of Tubercular Lymphoma of the Neck Abstract Am Jour Roentgenol 3 50 1916

FUJINAMI G The Roentgen Ray Treatment of Frost bite Sei I Kwai Med Jour 34 38 1915 English abstract of Japanese article Abstract Am Jour Roentgenol 2 784 1915

GASTON and NICOLAU Quelques cas d affections pilaires (tricophyties sycosis folliculites) traitées par les rayons X Bull Soc franç de dermat et syph 13 341 1902

GASTON and VIEIRA Essai de traitement des dermatose par la radiothérapie cas de favus soumis aux rayons X Bull Soc franç de dermat et syph 13 281 1902

GAUCHER E *Les résultats de la radiothérapie et de la radiumthérapie en thérapeutique cutanée* Bull de l Acad de méd 3 s 78 17 1915

GOECKERMAN W H Lupus Erythematosus as a Systemic Disease Jour Am Med Assn 80 542 1923

——— The Treatment of Lupus Erythematosus by Filtered X ray to the Gland bearing Regions of the Body Med Jour and Rec *120 530 1924*

HAHN R and ALBERS-SCHONBERG Die Therapie des Lupus und der Hautkrankheiten mittels Rontgenstrahlen Munchen med Wchnschr 47 284 325 363 1900

HALL-EDWARDS J On the Physiological and Therapeutic Effects of the Rontgen Rays the Treatment of Lupus Edinburgh Med Jour n s 7 139 1900

HARTZELL M B *A Case of Lupus Erythematosus* Improved by Exposure to the X ray Jour Cutan Dis 24 280 1906

——— Granuloma Annularis Jour Cutan Dis 28 302 1910

——— Discussion of Case of Dermatitis Herpetiformis Jour Cutan Dis 30 279 1912

HYDE J N [Epithelioma on Lupus Vulgaris] *Jour Cutan Dis 29 641 1911*

KAPLAN I L Tuberculous Adenopathy in Young Children Treatment with Radiation Arch Pediat 61 119 1944

KETRON, L W Report of a Case of Acnitis With a Study of the Point of Origin of the Pathological Process, Bull Johns Hopkins Hosp, **26**, 111, 1915

KNOWLES, F C Acnitis in the Negro, Jour Cutan Dis, **35**, 61, 1917

KNOX, J T Treatment of Lupus Vulgaris With *X*-rays, Report of a Case With Cure, Jour Am Med Assn, **35**, 1210, 1900

KNOX, R *X*-rays and Radium Rays in the Diagnosis and Treatment of Enlarged Lymphatic Glands, Arch Radiol and Electrotherap, **21**, 27, 1916

LASSUEUR Le traitement du lupus érythémateux par les rayons X, Arch. d'électric méd, **17**, 248, 1909

LEE, J A The Therapeutics of the *X*-rays, Brooklyn Med Jour, **16**, 85, 1902

LEONARD, C L The Treatment of Tuberculous Cervical Adenitis by the Roentgen Rays, Jour Am Med Assn, **54**, 1596, 1910

LIEBERTHAL, D Epithelioma on Lupus Vulgaris, Jour Cutan Dis, **29**, 640, 1911

MACLEOD, J M H Epithelioma Developing on an *X*-ray Scar in a Case of Lupus Vulgaris, Brit Jour Dermat, **13**, 104, 1906

MOBERG, L Ueber die Behandlung von Lupus erythematosus mit Rontgenstrahlen, Arch f Dermat u Syph, **107**, 47, 1911

MOLYNEUX, E S Radium in the Treatment of Tuberculous Adenitis, Brit Med Jour, **2**, 705, 1919

——— Radium as a Curative Agent for Tuberculous Glands, Lancet, **2**, 804, 1922

MONTGOMERY, F H Lupus Erythematosus, Eighteen Years' Duration, Jour Cutan. Dis, **24**, 86, 1906

MOWAT, H The *X*-ray Treatment of Tuberculous Glands, Brit Med Jour, **2**, 11, 1914

NADLER, A G A Case of Scrofuloderma Treated With the Roentgen Ray, Jour Cutan Dis, **28**, 609, 1910

NEWCOMET, W S Radium and Radiotherapy, Philadelphia, Lea & Febiger, 1914, p 187

ORMSBY, O S Granuloma Annulare (?), Jour Cutan Dis, **31**, 351, 1913

——— A Practical Treatise on Diseases of the Skin, 5th ed, Philadelphia, Lea & Febiger, 1937, p 783

PFAHLER, G E Carcinoma and Tuberculosis Treated by the Roentgen Rays, Jour Am Med Assn, **41**, 1406, 1903

PRINGLE, J J Multiple Epithelioma Developing Upon Lupus Erythematosus, Brit Jour Dermat, **12**, 1, 1900

PUSEY, W A [Epithelioma on Lupus], Jour Cutan Dis, **29**, 641, 1911

PUSEY, W A, and CALDWELL, E W The Practical Application of the Roentgen Rays in Therapeutics and Diagnosis, 2d ed, Philadelphia, W B Saunders Company, 1904, pp 390, 394

RATERA Two Cases of Scrofuloderma and Tuberculous Fistulas Cured by Radiotherapy, Actas dermosif, **8**, 100, 1915, Abstract, Jour Cutan Dis, **34**, 571, 1916

ROBINSON, A [Lupus Erythematosus Treated by *X*-rays, Two Cases], Jour Cutan Dis, **21**, 102, 1903

RODMAN, W L, and PFAHLER, G E The Present Status of the Treatment of Superficial Carcinoma and Tuberculosis by Means of the *X*-rays, Philadelphia Med Jour, **11**, 970 1903

ROSH, R, and QUINN, W P Roentgen Rays in Treatment of Cervical Lymphadenitis, Radiology, **41**, 464, 1943

ROTHBART, L Rontgentherapie der Erfrierungen, Gyógyászat, No 9, 1922, Abstract, Dermat Wchnschr, **76**, 496, 1923

SCHIFF, E [Guérison d'unlupus érythémateux par les rayons de Rontgen], Semaine méd, **18**, 464, 1898

——— Neuere Erfahrungen auf dem Gebiete der Radiotherapie, Wien med Presse, **40**, 57, 1899

SCHIFF, E, and FREUND, L [Sycosis mit Ekzem], Klin -therap Wchnschr, **6**, 851, 1899

——— Beitrage zur Radiotherapie, Wien med Wchnschr, **48**, 1057, 1898

——— Weitere Beitrage zur Radiotherapie, in Beitrage zur Dermatologie und Syphilis, Festschrift gewidmet Dr I Neumann, Leipzig, 1900, p 805

SCHULTZ, F *X*-Ray Treatment of Skin Diseases, Translated by James Burnet, New York, Rebman Company, 1912, p 132

SIMPSON, F E Radium Therapy, St Louis, The C V Mosby Company, 1922, p 289

——— Radium in the Treatment of Cancer and Various Other Diseases of the Skin, Jour Am Med Assn, **67**, 1508, 1916

STARTIN J On X rays in the Treatment of Lupus and Rodent Ulcer Lancet 2 144 1901

STRUNSKY M Tuberculous Glands of the Neck Cured by the X ray New York Med Jour 96 743 1912

STÜMPKE G Lupuskarzinom und Rontgenstrahlen Dermat Wchnschr 62 226 1916

VARNEY H R Results in Radiotherapy Jour Am Med Assn 40 1577 1903

WEIL E A La *radiothérapie des adénoïdites tuberculeuses périphériques* Paris méd 6 260 1916 Abstract Am Jour Roentgenol 4 449 1917

WHITE C J Granuloma Annulare Jour Cutan Dis 30 278 1912

WICKHAM L and DEGRAIS P Radiumtherapy Translated by S Ernest Doré London Cassell & Co 1910 pp 231 134

WILLIAMS F H The Roentgen Rays in Medicine and Surgery 2d ed New York The Macmillan Company 1903 p 715

WINFIELD J M [Two Cases of Lupus Erythematosus Cured by X rays] Jour Cutan Dis 21 102 1903

ZEISLER J Unusual Case of Lupus Erythematosus Jour Cutan Dis 26 138 1908

——— [Epithelioma on Lupus] Jour Cutan Dis 29 641 1911

——— An Uncommon Case of Multiple Benign Sarcoid of the Skin Jour Am Med Assn 65 764 1915

CHAPTER XXXVI

VERRUCOUS LESIONS AND ERUPTIONS.

THE following entities will be discussed in this chapter:

1. Verruca Vulgaris
2. Miscellaneous Types of Verruca and Papilloma
3. Cornu
4. Callositas
5. Verruca Plantaris
6. Keratosis.
7. Leukoplakia
8. Kraurosis Vulvæ
9. Keratosis Follicularis (Darier's Disease).
10. Xeroderma Pigmentosum
11. Acanthosis Nigricans

VERRUCA VULGARIS.

X-rays and radium are of value for the treatment of the common wart. In an early series of 88 cases, with known results, mostly with multiple lesions, 74 (84 per cent) were permanently cured as a result of one or two treatments. Twenty-six (30 per cent) were cured in one treatment. They were all treated with unfiltered *x*-rays. The dose was 300 r in most instances. A few lesions received 375 r and 450 r.

The percentage of cures with *x*-rays and radium are about the same as with bismuth, wart vaccine, psychotherapy, and other nondestructive methods.

In a later series of 60 patients with known end results, there were 38 (63 per cent) cures, 19 (50 per cent) were cured with one treatment. Most of the patients presented several lesions. The statistics represent the number of patients, not the number of lesions. In the second series the dose was about the same as in the first series, but for the most part the lesions were larger and they had been unsuccessfully treated by other methods. The percentage of cures might have been higher if the dose were larger. The percentage of cures for the total of 148 patients was 76. There were no recurrences and there were no bad results.

If a lesion has not disappeared after two doses at monthly intervals, it is unwise to persist in the treatment. If the treatment is continued beyond this point a third-degree radiodermatitis may develop insidiously under the wart. This is an important fact and should be borne in mind.

The advantages of irradiation are: No danger of infection; permanence of cure, absence of pain and scarring, rapidity and facility of the treatment.

The lesion often disappears in about three weeks subsequent to the first treatment. It may improve considerably in the second and third weeks and regain its original size in the fourth week. If so it often disappears three weeks subsequent to the second treatment. Rarely, irradiation of one wart in a case where there are multiple lesions scattered over both hands may be followed by the disappearance of all warts on one or even on both hands. Phenomena of this kind have been noted by Delbanco, Halberstaedter, by us and others.

Fig 238 —Verruca vulgaris before treatment. Note that the lesion extends under the side of the finger nail.

Fig 239 —Same as Fig 238 after two x ray treatments. There was no recurrence. Two months after the last treatment it was impossible to determine the position of the former lesion.

Perthes (1901) and Sjogren and Sederholm (1903) were the first to call attention to the value of roentgenization as a treatment for the common wart. Since then many roentgenologists have obtained satisfactory results.

Technic.—The common wart is composed of a very thick rete (acanthosis) and, as a rule, there is considerable thickening of the horny layer (hyperkeratosis). Also the lesions are usually very small. For these reasons it is permissible to apply a larger dose than would be tolerated by the normal skin without a sharp reaction. It is essential that the normal skin around the wart be protected with lead foil to the very edge of the lesion. The first dose may be 300 r. In many instances this amount will suffice to effect a permanent cure, the wart disappearing in three or four weeks. If the lesion, instead of disappearing, is considerably reduced in size as a result of the first treatment another dose of the same size is administered four weeks subsequent to the first application. If the lesion, as a result of the first treatment, has not become smaller, and there has been no reaction, the second dose may be increased. The dose will depend on the size and thickness of the lesion also on its location and the age of the patient. Usually the second dose is 450 r or 600 r, but 900 r and 1200 r have been administered to small, thick lesions. With the larger

doses the percentage of cures will be greater. We prefer one or two moderate doses, and if the result is not satisfactory, electrodesiccation or some other method

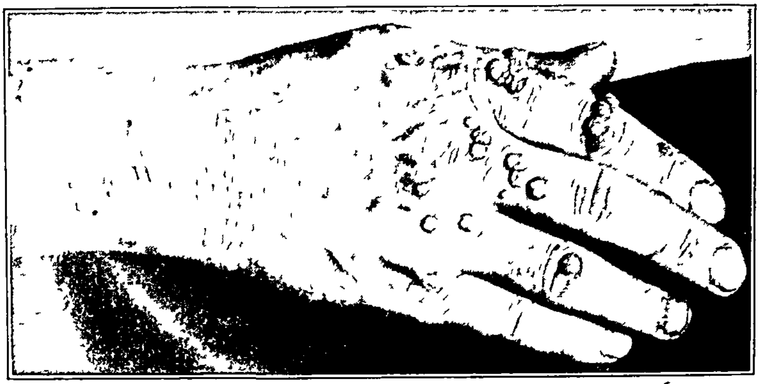

FIG 240 —Verruca vulgaris with multiple lesions, before treatment

It is advisable here to interject an important warning If the dose is sufficiently large there will, of course, be a reaction But this reaction is not noticed as an erythema The wart becomes sensitive to the touch and perhaps a little larger, the increase in size being due largely to the inflammation of the true skin At times evidence of inflammation may be noted in the skin around the lesion, skin that was not in the field of radiation It is important to bear these facts in mind, otherwise a reaction might be overlooked, a second applica-

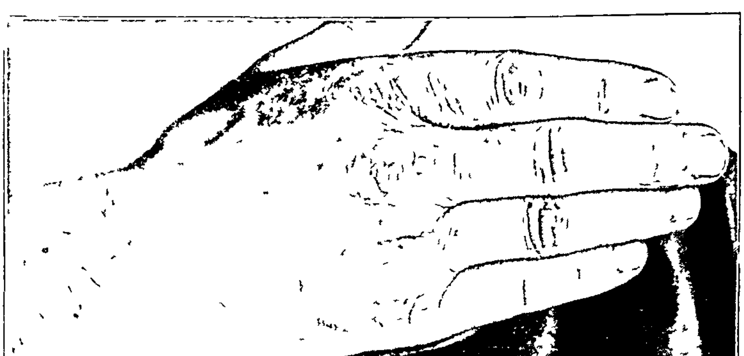

FIG 241 —Same as Fig 240 after one subintensive x-ray treatment

tion might then be made with the possibility of a third-degree radiodermatitis If the evidences of reaction as above outlined are manifest, the next treatment should not be given for at least two weeks subsequent to subsidence of the reaction. In such instances it is preferable to avoid further irradiation Some warts are very vascular and react to comparatively mild doses This fact, together with the fact that the thickness of the horny layer and epidermis varies in different warts, constitutes the basis for the conservative first dose, namely 300 r.

In cases of multiple verrucæ, with numerous lesions scattered over the hands or other parts it is too much of an undertaking to treat each lesion separately If there are only a few warts on a fairly level surface it requires only a few minutes to cut a hole for each wart in a piece of lead The whole affected area may then be exposed to the routine dose Lesions that are not on a level surface must of course, be separately exposed If the lesions are too numerous for the method just outlined the entire surface lesions and normal skin may be given a suberythema dose In cases of this kind it is a good plan to apply a thick zinc, bismuth, or barium paste to the normal skin between the lesions If the lesions do not disappear as a result of one such treatment, it is advisable to resort to some other method

A rather favorite location for the common wart is at the edge of a fingernail It often extends under the nail In such instances it is advisable to cut the nail until the verrucous surface is fully exposed before applying the rays Not infrequently a wart will extend entirely around a nail and involve the lateral surfaces of the finger Here we are dealing with a convex surface and it is often necessary to make two exposures, one exposure to each side care being taken to protect first one side and then the other and, also to prevent overlapping

The common wart may involve the mucous membranes of the lip nose and eyelid In such locations it is often more convenient to use radium

Filtration —There are theoretical grounds for an argument in favor of filtered radiation in the treatment of verruca vulgaris We have tried both filtered and unfiltered radiation and in the majority of instances no difference was noted in the matter of efficacy In no instance excepting in unusually large warts, has it been possible to cause the disappearance of a lesion with filtered radiation that failed to resolve under the influence of unfiltered radiation Very large warts however, should be treated with filtered rays The reasons for favoring unfiltered radiation are that considerably less time is required to administer the dose there is no greater safety with filtered radiation and, with the exception noted above efficacy appears to be the same with both filtered and unfiltered radiation

Radium —Our experience with radium in the treatment of verruca vulgaris is limited to a comparatively few cases In most of these cases the lesion has been in the nostril at the vermilion border of the lip, or at the mucocutaneous junction of the eyelid The results have been splendid with both beta and gamma rays depending on the size and thickness of the lesion

Lesions situated in the nostril can be irradiated by means of a radium tubular applicator Lead foil is wrapped around the tube a small window or diaphragm, is cut in the lead close to one end of the tube, with adhesive plaster the tube is fastened to one end of a wooden tongue depressor the wood acts as a handle by means of which the exposed part of the tube can be held against the lesion

for the desired length of time; the glass wall of the tube provides sufficient filtration for most cases. The same scheme is useful for lesions situated at the inner canthus or at the border of an eyelid. It is often possible to crossfire large lesions with beta rays from a tubular applicator. Used in this manner a 25-mg. or millicurie tube will often cure a lesion as a result of an exposure of from three to ten minutes, although thick lesions may require longer exposures. A half-strength, glazed applicator screened with 0.1 mm. aluminum, with suitable protection for normal skin, may be applied from fifteen to thirty minutes and even longer. Very thick lesions should be treated with gamma rays. The flat applicator just mentioned is screened with 1 mm. brass and 1 mm. aluminum, and held in contact with the lesion for one or two hours, or even longer, depending on the thickness of the lesion and especially of the horny layer. In general, the statements made in discussing the roentgen-ray treatment of warts will apply to the use of radium for the same purpose.

Abbe, Knox, Wickham and Degrais, Simpson and, in fact, most radium therapeutists testify to the efficacy of radium in the treatment of verruca vulgaris.

MISCELLANEOUS WARTS.

Papillomata of the skin and mucous membranes will often disappear subsequent to irradiation. Recurrences are uncommon. Abbe and others have obtained good results with radium in the treatment of papillomata of the tongue. We have encountered lesions that disappeared promptly and lesions that failed to improve at all when irradiated. More experience is required in order to classify the various types of warts and papillomata and to permit a proper selection of cases. The technic of application does not differ from that given for the treatment of verruca vulgaris.

We have found the flat juvenile wart very unyielding to both radium and x-rays. At times the result is good, but on the whole treatment has been disappointing. Allen reports a patient with flat warts scattered over the trunk. The eruption disappeared, apparently as a result of roentgenization. The histologic changes, however, were those of porokeratosis. Lustgarten made a clinical diagnosis of multiple senile or seborrheic warts. The lesions of both verruca plana juvenilis and the flat warts of adults have not yielded well to irradiation, excepting in a few instances.

Pfahler noted the disappearance of multiple verruca of the bearded region as a result of roentgenization. The treatment did not prevent the formation of new lesions. Personal experience with this type of wart has not been very satisfactory.

Wickham and Degrais, Newcomet and others report good results with radium in the treatment of warts or papillomata of the scalp; also vegetations of the vulva and glans penis associated with gonorrhea. We treated one case of condyloma acuminatum with x-rays

without benefit Schultz found that it required dangerous doses to cause involution in this type of wart

CALLOSITAS

We have treated several cases of callositas with unfiltered x-rays and filtered beta rays with good temporary results The lesions usually return unless the cause is removed

VERRUCA PLANTARIS

The first recorded instance of the successful treatment of a plantar wart with radiation is in a footnote on page 276 of Wickham and Degrais book, *published in 1912* The lesion was treated with radium MacKee published his first case treated with x-rays, in 1915

Hazen and Lichenlaub record the treatment with x-rays of 16 cases of plantar warts In many of the patients there were multiple lesions Fifteen of the patients were cured There was not a single recurrence The number of treatments ranged from one to seven Invariably the pain disappeared in from two to four days subsequent to the first treatment The dose was about 450 r, unfiltered, every three or four weeks Some of the patients remained under observation for six years Wise successfully treated 7 cases without recurrences He used 300 r, unfiltered, at intervals of one month Michael records 45 cases with known results, 43 were cured, 34 were cured with one treatment The dose ranged from 450 to 750 r unfiltered There were no recurrences The thickened horny layer was not removed before the treatment was applied

In our first series of cases there were 30 known results 20 were cured, 6 were cured in one treatment The dose was usually 300 r unfiltered Occasionally 450 r and 600 r were administered In many instances there were multiple lesions The horny layer was cut away as much as possible before the application

In a second series of 36 patients with known endresults, there were 19 (53 per cent) cures, 8 (42 per cent) were cured in one treatment The total number of cases was 96 of which 49 (51 per cent) were cured There were no recurrences In the second series the dose was the same as for the first series, but in most of the patients the thickened horny layer was not removed prior to irradiation

Montgomery some years ago described two varieties of plantar warts namely the common (vulgar) and the mosaic The latter is recognized by multiple puncta Dermatologists have accepted Montgomery s classification It is important to make the distinction because the mosaic wart is radioresistant while the common wart yields well to irradiation We have had no success with irradiation *in the case of the mosaic wart with doses that we are willing to give* As a rule this wart will not yield even to very large doses

Montgomery, Oliver, Beers, Lutz and others have obtained a higher percentage of cures than we have in the case of the common plantar wart, but they employ somewhat larger dosage. We have seen many bad results following a single large dose (1200 r or more) or repeated smaller doses Plastic surgeons are busy repairing these injuries.

There was a time when irradiation was considered the therapeutic method of election for the plantar wart. It is still an excellent treatment for the common variety but not always the method of choice. Karp's "loop method" gives a higher percentage of cures than does irradiation in the case of the common variety. Vaccine is excellent sometimes for either type Good results are obtained, also, with psychotherapy, bismuth, salicylic acid and other methods

Technic.—Each lesion, when the lesions are multiple, should be separately treated The opening in the lead shield should fit the lesion exactly, normal skin must not be included in the field of radiation. If caustics have been applied, or if the lesions are inflamed, it

Fig 242 —A plantar wart before treatment

Fig 243 —Same as Fig 242, after one *x*-ray treatment This patient was seen thirty years later No recurrence and no *x*-ray sequelæ

is advisable to postpone the treatment for a week or two Many lesions will disappear as a result of the administration of a single intensive dose of unfiltered radiation (300 r), especially if the thickened, horny layer is removed as much as possible with a razor blade A week or two subsequent to the treatment the patient is likely to notice that the lesion is a little more sensitive than usual; then sensitiveness to pressure disappears entirely and, frequently, the lesion disappears in from three to six weeks If there is no improvement, and there has been no *x*-ray reaction by the fourth week, a second dose is given. Because of the thickened horny layer, if it is not removed, and the small size of the lesions, large doses are permissible—from 450 to 600 r and even 900 r These large doses are not administered unless the hyperkeratosis, of which the lesion is mainly composed, is thick. The thickened horny layer acting as a *filter* prevents an excessive amount of radiation from reaching the underlying tissue (derma).

If a lesion does not disappear as a result of two such doses no benefit and, perhaps, serious injury may result if the treatment is continued.

If a radiodermatitis occurs it does so under the thick horny layer, and it is likely to be overlooked. In this event repetition of treatment may be followed by a third-degree radiodermatitis. The danger signals are swelling or a pushing outward of the lesion due to underlying inflammation, increased and persistent sensitiveness to pressure and inflammation of the surrounding, unirradiated skin. The authors have seen the insidious development of third-degree reactions under these lesions, due to the too persistent treatment of stubborn lesions. If a lesion does not disappear as a result of two treatments it is preferable to resort to some other therapeutic method. If more than this amount of treatment is given the wound may not heal well after the lesion has been removed by electrosurgery or other surgical method.

Filtration.—With a few exceptions, all our cases were treated with unfiltered radiation. The exceptions were unusually large and thick lesions. It is possible that better average results might be obtained with filtered radiation. More experience will be required before this question can be definitely decided. Both types of radiation seemed to give the same results in lesions of average size. Lesions of this size that failed to respond to unfiltered radiation did not improve when treated with filtered radiation. Very large and thick lesions seemed to do better with filtered rays.

The very thick horny layer acts as a filter and permits the application of a rather large dose of unfiltered radiation without injury to the derma. With filtered radiation there is less absorption by the horny layer; hence the amount received by the derma as compared to that received at the surface is greater than with unfiltered radiation. Theoretically, therefore, the therapeutic effect of filtered radiation might be superior to that of unfiltered radiation, the dose being the same in both instances.

We prefer unfiltered radiation as a routine because of economy in time; in all but unusual cases the effect seems to be the same for filtered as for unfiltered radiation; if, inadvertently, the filter should be omitted and the dose is estimated as though a filter were being used, the effect might be very unpleasant if not serious. This may seem to be a foolish suggestion, but we have known this technical error to happen on many occasions to many different operators, all of whom were careful, conscientious men and several of whom were experienced roentgenologists.

Radium.—Personal experience with radium in the treatment of verruca plantaris is limited to 20 cases. Insofar as can be determined, from such limited experience, the results are the same as with x-rays, as, indeed, should be the case. Bissell reports cures of both plantar warts and corns with radium. In several of our cases lesions that failed to improve under roentgenization were equally resistant to both beta rays and gamma rays. Small lesions may be treated with penetrating beta rays, especially if most of the horny layer is first removed, a screen of 0.1 mm. aluminum being sufficient. A half-

strength, flat, glazed element applicator, screened with 0.1 mm. aluminum, may be placed in contact with the lesions for from fifteen to thirty minutes or even longer, depending on the thickness of the horny layer. Screened with 1 mm. brass and 1 mm. aluminum, and in contact with the lesion, the exposure will be one or two hours or even longer. A 25-mg. or millicurie tube, screened with 1 mm. brass, 0.5 mm. silver and 1 mm aluminum, and held ½ inch from the surface, may be applied for three to six hours. The flat applicator is the popular method of applying radium. Most, if not all, of the beta rays will be absorbed by the horny layer of very thick lesions. In such instances it is presumably the gamma rays that prove effective whether or not a heavy filter is used What has been said relative to the use of *x*-rays in this condition will apply, also, to the use of radium.

CORNU.

Hard corns are unyielding to both *x*-rays and radium. It usually requires one large dose or several moderate doses at monthly intervals to effect a clinical cure. Pirie obtains excellent results with a dose consisting of 1200 r. It is not possible to establish a cure unless friction is avoided. The lesions frequently recur. The technic of application and the precautions to be taken are the same as in the treatment of verruca vulgaris and verruca plantaris and need not be repeated here. It is our opinion that hard corns should be treated by removing the cause, rather than by any form of local or palliative treatment.

Soft corns, situated between the toes, usually undergo complete involution as a result of one or two treatments. The best results obtained by us have been with tubular radium applicators. The tube is prepared as described in the radium treatment for verruca vulgaris of the nostril (above). No filter other than the glass wall of the tube is required. We have had excellent results with a small flat half-strength radium element applicator (Beer applicator) which is lightly filtered, applied in contact for twenty minutes. It is well to keep in mind that, as Weidman pointed out years ago, the majority of soft corns are caused by fungi (dermatophytosis).

KERATOSES.

Under this heading will be discussed senile keratosis, seborrheic keratosis, arsenical keratosis, *x*-ray keratosis and miscellaneous keratoses.

Senile Keratosis.—The senile keratosis is dangerous because it so often eventuates in epithelioma, usually of the squamous-cell type. As a rule the lesion is small, gray or brown and consists, clinically, of a thickened, adherent horny layer. Occasionally there is considerable hyperplasia of the rete—acanthoma; or the lesion may be verrucous.

A common site is the mucosa of the lips where the lesion is especially dangerous Because of the danger of eventual malignancy the senile keratosis should be completely destroyed This can be done in various ways Scalpel surgery or electrosurgery are possibly the methods of choice However, they can be destroyed with x-rays or radium Many patients, because of the fear of surgery, or for cosmetic reasons, prefer to try x-rays or radium It is well to bear in mind that very heavy doses may result in a defect that is as disfiguring as would be the scar resulting from excision and as dangerous as was the original lesion, also that excision has the advantage of microscopic diagnosis

From one to four erythema doses of x-rays or gamma rays depending upon the size and thickness of the lesion often will suffice for a permanent cure Recurrences should be treated surgically Beta radiation is efficacious for small thin lesions It is preferable to remove the horny layer first Then a half-strength flat radium applicator screened with 0 1 mm aluminum, may be applied for an hour

Fig 244 —Senile or seborrheic keratosis with cutaneous horn

Fig 245 —Same as Fig 244 showing exfoliation after one intensive treatment

Seborrheic Keratosis —This lesion is not nearly so dangerous as is the senile keratosis It occasionally gives rise to epithelioma usually of the basal-cell type The keratotic type consists, as a rule, of a thickened horny layer that is waxy and that can be easily removed The color is brown or a mixture of brown and black This type responds fairly well to moderate doses of x rays or radium It is customary to remove the horny layer and apply lightly filtered beta rays (half-strength flat radium applicator 0 1 mm aluminum for twenty or thirty minutes) or a dose of unfiltered x-rays consisting of about 300 r

The so-called nevoid type is a thick elevated lesion It ranges in size from the head of the common pin to that of a 50-cent piece It resembles a nevus This type unless very small and of comparatively recent development, is in our experience, resistant to moderate doses of x rays and radium We prefer other methods of treatment

At times, the seborrheic keratosis may be verrucous. Such lesions, also, are insensitive to irradiation.

Cutaneous Horns.—These usually are associated with the senile keratosis. They may develop in apparently normal skin, especially in young persons. Occasionally they develop in a seborrheic keratosis. In adults the cutaneous horn is dangerous. They do not respond particularly well to irradiation. We prefer to destroy them with some form of surgery.

Arsenical Keratoses.—Individual keratoses due to arsenic and also those due to tar, paraffin, etc., will at times disappear under the influence of *x*-rays or radium. However, it is not a satisfactory method. We have never treated the so-called arsenical palm with either of these agents.

X-ray Keratoses.—The beta rays of radium will often cause the disappearance of the painful and dangerous keratoses that develop in "*x*-ray skin." The lesions may also be made to disappear with *x*-rays and gamma rays. Recurrence, however, is the rule.

McDonnell, who had scattered *x*-ray keratoses over the dorsal surface of one hand, reports the disappearance of the lesions as a result of twenty-one weekly *x*-ray treatments, the radiation being allowed to spread over the entire hand. Sequeira, commenting on McDonnell's result, cautions against the possible remote effects. We agree with this admonition.

Sequeira (1908) was probably the first to treat such lesions with the *x*-rays, Tousey (1915) seems to have been the first to try radium. The lesions were on his own hands. Four months later Abbe reported the cure of a number of cases. Abbe also reports the cure with radium of several *x*-ray epitheliomata. Degrais and Bellot have cured *x*-ray keratoses and ulcers with radium.

In his article Abbe calls this phenomenon an apparent paradox. The words were well chosen, the paradox is apparent and not real. The development of a keratosis in skin that has been injured by *x*-rays may be at least partly idiosyncratic. It is the same thing that happens in xeroderma pigmentosum, sailors' skin, farmers' skin, etc. The point is that the skin has been altered by *x*-rays, actinic rays, or other physical and chemical agents. The cells are compelled to adapt themselves to the new environment and in doing so they develop new characteristics and power of independent growth. As far as is known, a preepitheliomatous keratosis is fundamentally the same whether due to *x*-rays, sunlight or other causes. If *x*-rays and radium rays can cure keratoses and early cutaneous epithelioma due indirectly to actinic rays, and they can do so, there is no good reason why they should not be equally efficacious in similar lesions caused indirectly by *x*-rays or radium rays. It must not be assumed from this argument that radium or *x*-rays are advocated for *x*-ray keratosis. As a matter of fact, we are opposed to the use of either *x*-rays or gamma rays in these cases. The derma and even the subcutaneous tissue is usually sclerotic in

these cases, and large doses of either gamma rays or x-rays will add to the injury and pave the way for additional trouble

LEUKOPLAKIA

The first recorded instance of the treatment of leukoplakia with x-rays thus far located is the treatment of 3 cases by Pusey in 1904 In treating carcinoma of the mucosa of the right cheek Pusey noticed that the associated leukoplakia which involved the entire cheek totally disappeared The patient lived only a few months but during this time there was no recurrence Improvement but not a cure was obtained in one case of very extensive leukoplakia and a clinical cure in another patient who had a patch of leukoplakia the size of a five-cent piece In this case a moderate radiodermatitis was produced In 1911 Pusey in discussing the treatment of leukoplakia, states "I have succeeded in curing a good many of them by the use of x-rays" Hazen and Eichenlaub failed to obtain satisfactory results

Freundenthal, in 1906 treated a case of extensive leukoplakia with radium The ulceration and pain disappeared but the leukoplakia remained Wickham and Degrais treated several cases, some of which were cured, others were improved Knox, Sencer, Guy, McGlasson and others report cases that have been improved or cured Knox has obtained good results with both x-rays and radium Abbe finds radium a positive cure for leukoplakia At the Memorial Hospital in New York and in other institutions it has long been known that extensive leukoplakia of the mouth will completely disappear when treating epithelioma of the mouth with radium, but recurrence is the rule

We have been disappointed with both x rays and radium in the treatment of this condition X-rays were tried several years ago on a number of cases but the results were so poor and the difficulty of proper application so great that the work was discontinued For a period of ten years efforts were confined to radium Small patches have often disappeared as a result of one application of beta rays—an exposure sufficient to effect a first-degree reaction Many of these patients have been free of recurrence for many years No improvement has resulted unless the treatment has caused a reaction Not a single case of extensive leukoplakia was cured In numerous instances the lesion disappeared only to return Even some of the small *lesions failed to disappear and if they did disappear many of them* recurred

Leukoplakia is neither syphilis nor cancer It is a keratosis and dyskeratosis of unknown etiology, in which epithelioma frequently develops—epithelioma of the squamous-cell type Therefore leukoplakia must be considered one of the dangerous forerunners of cancer The condition when extensive is rebellious to all forms of

treatment, which makes the uncertain results of radium all the more disappointing and discouraging

Gamma radiation can be applied to the entire mouth if so desired and if the dose is strong enough to cause a reaction the leukoplakia, even when extensive, is likely to disappear. However, it usually recurs. The new *x*-ray tubes designed for irradiating cavities can be used for the same purpose In our opinion, the results of irradiation in leukoplakia are so unsatisfactory that the method is not indicated except in selected cases It is preferable to keep patients with leukoplakia under observation during the remainder of their lives and to treat small areas that are misbehaving either with *x*-rays, radium or with some form of surgery, preferably the last

KRAUROSIS VULVÆ.

Kraurosis is included in this group of diseases because often among its symptoms is leukoplakia of the vulva.

We have treated 7 cases of kraurosis vulvæ. One patient, besides atrophy, leukoplakia and intense itching, had an epithelioma. The epithelioma was excised before irradiation. After three weekly *x*-ray treatments the itching ceased. There was no change in the leukoplakia. The subsequent history is unknown. Another patient with leukoplakia and intense itching failed to improve after several suberythema treatments The condition in both cases was of long duration In the case of the third patient the duration was two years. The mucosa was thick, it was glazed in places and milky-white in other places. There was a tenacious discharge and intense itching After the second treatment the itching, thickening and discharge disappeared. The leukoplakia had changed from white to gray. In the remaining cases the itching disappeared, but there was no other change In 2 patients small areas of leukoplakia and erosion were cured with beta rays of radium. Several patients were treated with electrosurgery for epitheliomas and areas of persistent leukoplakia There were recurrences of itching, leukoplakia and epithelioma in several cases. Runge treated 2 cases of kraurosis vulvæ with *x*-rays without improvement in either case

In the treatment of kraurosis vulvæ the fact that it is a forerunner of cancer must be kept in mind. It would seem advisable to discontinue treatment if the pruritus is not relieved as a result of three or four weekly treatments of 75 r low voltage unfiltered *x*-rays

KERATOSIS FOLLICULARIS.
(Darier's Disease.)

We had one case of Darier's disease the lesions of which disappeared as a result of roentgenization. There were a few scattered areas of the lesions distributed over the body surface. The eruption in some

areas underwent complete involution subsequent to a single suberythema dose Other areas required two or three such treatments Nothing is known relative to the subsequent history of the patient It was not a severe case, the duration was only a few months The clinical diagnosis was confirmed microscopically

Lieberthal recorded the first case of Darier's disease ever treated with x-rays (1904) Ritter cured a very extensive case Stout saw marked improvement in 1 patient, even the untreated lesions underwent involution Mook obtained good results in 4 cases Scheer obtained substantial improvement in 1 patient and G H Fox Engman and Mook saw considerable improvement in 1 case H Fox has been disappointed with results obtained with x rays in this disease

In recent years, as shown by Peck, better results are obtained with vitamin therapy than can possibly result from x-ray treatment

XERODERMA PIGMENTOSUM

The keratoses and the epitheliomata occurring in this disease may be cured with x rays or radium The technic of application will be found in this chapter under the heading of Keratosis and in the chapter on Epithelioma We have treated only 2 cases, and in both instances the epitheliomata, which were of the basal-cell variety, were more stubborn than is usual for this type of epithelioma The keratoses disappeared but many of them recurred

Perrin and Dupeyrac were the first to record (1906) the use of x-rays in this disease They were able to make the warty lesions and malignant tumors disappear in their 1 case Jamieson and Allen have reported the disappearance of keratoses and epithelioma following irradiation

Of course x-ray or radium treatment does not modify the prognosis of this dreadful and hopeless disease, but such treatment may give the poor little patients temporary comfort We prefer methods other than irradiation for the management of this disease

ACANTHOSIS NIGRICANS

Wise reports a case of *acanthosis nigricans of the juvenile type* occurring in a young woman She presented typical and well pronounced lesions implicating practically the entire body, with rugose and papillary growths in the axillæ and groins A series of weekly roentgen-ray treatments, extending over a period of five *months*, resulted in complete involution of the lesions, so that her skin became normal in appearance and texture We saw this patient both before and after treatment, and can confirm the diagnosis and the completeness of the clinical cure The eruption followed the decapsulation of the kidneys Cognizance is taken of the fact that the juvenile variety of this disease occasionally undergoes spontaneous involution All that can be said in this connection is that the eruption had lasted for

a long time and had not been influenced by other remedies Involution began with the institution of roentgen therapy and it was rapid, continuous and complete

BIBLIOGRAPHY

ABBE, R Radium Efficiency in Non-Malignant Surgical Conditions, Med Rec, **90,** 47, 1916

ALLEN, C W Case of Flat Multiple Senile Warts (Supposed Porokeratosis) Cured by the *X*-Ray, Jour Cutan Dis, **23,** 312, 1905

BEERS, N T, and LUTZ, M H Plantar Warts Suggested Technic for Their Treatment by Radium, Brooklyn Hosp J, **2,** 143, 1940

BISSELL, J B Radium in Various Surgical Conditions, New York State Jour Med, **16,** 590, 1916

DEGRAIS, P, and BELLOT, A Curiethérapie des radiodermites épithéliomateuses professionnelles, Presse méd, **28,** 364, 1920

ENGMAN, M F, and MOOK, W H Keratosis Follicularis, Jour Cutan. Dis, **31,** 329, 1913

FOX, G H Darier's Disease, Jour Cutan Dis, **29,** 181, 1911

GUY, W H, in discussion on Hazen, H H, and Eichenlaub, F J Leukoplakia Buccalis, Jour Am Med Assn, **79,** 1489, 1922

HALBERSTAEDTER, L Verschwinden samtlicher Warzen nach Rontgenbehandlung einer kleinen Anzahl derselben, Dermat Wchnschr, **55,** 1522, 1912

HAZEN, H H, and EICHENLAUB, F J The Roentgen-Ray Treatment of Verruca Plantaris, Jour Am Med Assn, **74,** 1311, 1920

——— Leucoplakia Buccalis, Jour Am Med Assn, **79,** 1487, 1922

JAMIESON, W A Case of Xeroderma Pigmentosum After Treatment by the *X*-Rays, Lancet, **1,** 105, 1903

LIEBERTHAL, D A Case of Darier's Disease, Jour Am Med Assn, **43,** 242, 1904

MCDONNELL, R A [*X*-Ray Treatment of *X*-Ray Burns], Jour Cutan Dis, **33,** 312, 1915

MCGLASSON, I L, in discussion on Hazen, H H, and Eichenlaub, F J Leukoplakia Buccalis, Jour Am Med Assn, **79,** 1489, 1922

MICHAEL, J C Roentgen-Ray Treatment of Verruca Plantaris, Arch Dermat and Syph, **13,** 658 1926

MONTGOMERY, A H, and MONTGOMERY, R M Roentgen Therapy of Plantar Warts, New York State Jour Med, **41,** 371, 1941

——— Common Hyperkeratotic Lesions of the Foot, Jour Am Med Assn, **124,** 756, 1944

MOOK, W H Report of Four Cases of Keratosis Follicularis (Darier's Disease), Jour Cutan Dis, **30,** 722, 1912

OLIVER, E A Verruca Plantaris, Arch Dermat and Syph, **42,** 302, 1940

PERRIN and DUPEYRAC Xeroderma pigmentosum avec néoplasies guéries par la radiothérapie, Marseille méd, **42,** 730, 1905

PFAHLER, G E Verrucæ Treated With the *X*-Ray, Jour Cutan Dis, **30,** 493, 1912

PIRIE, A H The Action of Roentgen Rays on Corns, Am Jour Roentgenol, **12,** 482, 1924

SCHAMBERG, J, in discussion on Trimble, W B The Mottled Chin in Syphilis, and Other Dermatological Observations, Jour Cutan Dis, **29,** 576, 1911

SCHEER, M A Case of Darier's Disease in Its Early Stages, Jour Cutan Dis, **34,** 837, 1916

SCHULTZ, F *X*-Ray Treatment of Skin Diseases, Translated by James Burnet, New York, Rebman Company, 1912, p 146

SENEAR, F E, in discussion on Hazen, H H, and Eichenlaub, F J Leukoplakia Buccalis, Jour Am Med Assn, **79,** 1489, 1922

SEQUEIRA, J H Comment on R A McDonnell's letter [Chronic *X*-Ray Dermatitis Cured by *X*-Rays], Jour Cutan Dis, **33,** 554, 1915

STOUT, D Case of Darier's Disease, Jour Cutan Dis, **24,** 581, 1906

——— A Case of Generalized Darier's Disease, Previously Shown, Jour Cutan Dis, **25,** 126, 1907.

WICKHAM, L, and DEGRAIS, P Radiumtherapy, Translated by S Ernest Doré, London, Cassell & Co, 1910, pp 155, 276

WISE, F Acanthosis Nigricans Following Decapsulation of the Kidneys, Jour Cutan Dis, **36,** 35, 1918

——— Roentgen-Ray Treatment of Widespread and Generalized Diseases of the Skin, Jour. Am Med Assn, **73,** 1491, 1919.

CHAPTER XXXVII

NEVI AND CONGENITAL KERATODERMATA

The diseases or conditions discussed in this chapter are

1 Angioma
   - Nevus Flammeus
   - Nevus Vasculosus
   - Angioma Cavernosum
2 Lymphangioma
   - Lymphangioma Cavernosum
   - Lymphangiectodes
   - Angiolymphangioma
   - Angiokeratoma
3 Nevus *Pigmentosus*
4 Nevus Pilosus
5 Nevus Verrucosus
6 Adenoma Sebaceum
7 Ichthyosis and Allied Conditions
8 Nevus Araneus and Telangiectasia

X-rays and radium have a limited field of usefulness in this group of dermatoses when the group is considered as a whole The results of radium therapy in some types of angioma are, however, very striking

ANGIOMA

The results obtained with x-rays and radium in this nevus will depend upon the particular type of angioma, its duration and the method of applying the radiation There is some confusion relative to the classification and nomenclature of the various clinical varieties of angioma For convenience angioma may be divided into three clinical types

1 Nevus flammeus (port-wine mark)
2 Nevus vasculosus (strawberry mark)
3 Angioma cavernosum (cavernous angioma)

These clinical types will be separately considered

Port wine Mark —Port-wine marks are usually located on the face and neck and vary in size and color They may of course, occupy any part of the body They may be no larger than a dime or they may occupy one entire side of the face and neck They may be pale red (pink) *dark red or bluish red* *They are never elevated above the level of the skin* Occasionally, angiomatous tumors may develop in a port wine mark

The *x*-rays and the gamma rays of radium are of no service in this condition. We have seen an *x*-ray technician with a port-wine mark of the anterior surface of the left forearm and back of the left hand. For several years these parts received daily exposures of unfiltered radiation while making fluoroscopic examinations. Finally, the skin became atrophic, keratoses appeared and two of the keratoses developed into epithelioma. The nevus was still present and, according to the patient's statement, had not changed in color since he was a boy. We have tried roentgen therapy in cases of port-wine mark without noting any alteration in color. Of course, if the treatment is carried to destruction of the upper part of the derma the result may be improvement in the nevus, but at the expense of serious *x*-ray sequelæ later in life.

Not much more can be said relative to the beta rays of radium. Hartigan reports the eradication of a port-wine mark which involved most of the left side of the face. Thirty-nine applications were made with an unscreened radium applicator. Superficial ulceration occurred after most of the treatments. Pinch was unable to obtain satisfactory results in this type of nevus with radium after several months of treatment. He used a screen of 0.1 mm of aluminum. He advises caution in these cases because of the possibility of sequelæ. Jones failed to obtain good results with very lightly screened radium. Simpson recommends radium treatment. He employs a toile type radium applicator, screened with 0.01 mm or 0.02 mm. aluminum. Wickham and Degrais have caused the disappearance of port-wine marks, but they admit atrophy and telangiectasia as sequelæ, and also aver that this type of nevus is exceedingly stubborn. We have failed to modify port-wine marks with radium without effecting a sharp beta-ray reaction. It is our opinion that neither *x*-rays nor radium should be employed in this type of nevus, and this is the consensus. We hold the same opinion relative to grenz rays, thorium X, radon ointment, etc.

Nevus Vasculosus (*Strawberry Mark*).—In this type of angioma the lesion is red and it is elevated to a greater or lesser degree above the surface of the skin. The lesions involve only the superficial vessels and vary in size from a pinhead to an adult hand. They are soft in consistency and tend to enlarge for a few years, after which they may undergo involution, which may be spontaneous or which may be due to ulceration or traumatism. They occur perhaps most frequently on the face but they are seen on nearly all parts of the body.

X-rays and gamma rays are capable of curing this type of angioma but the effect of beta rays of radium is so superior that *x*-rays and gamma rays are seldom used.

The results of beta-ray therapy in nevus vasculosus are so striking, so perfect, that they may be placed among the most notable achievements of radium therapy in the treatment of cutaneous diseases.

In small lesions in infants one or two treatments will often suffice for

complete disappearance of the nevus Larger and thicker lesions may require several treatments

A flat, glazed radium element applicator, screened with 0 1 mm aluminum is to be preferred A half-strength applicator so screened will usually effect erythema of the skin of an infant in about fifteen or twenty minutes It is possible to cure these lesions without even

Fig 246 — A large strawberry mark on the forearm

a first-degree reaction and it is preferable to avoid such reactions Therefore the first treatment should be about twelve or fifteen minutes Usually one or two such treatments, a month apart will suffice for the desired result Many operators advise very strong treatment with vigorous reaction Such treatment affords spectacular

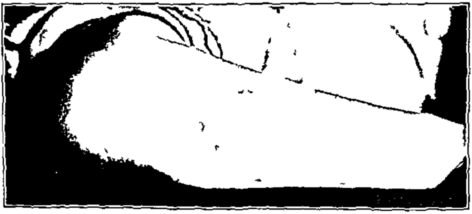

Fig 247 —Same as Fig 246 after radium treatment

results but sequelæ usually develop We prefer very conservative treatment It is well to shield closely The earlier in life these lesions are treated the better will be the result They are very radiosensitive in infancy much less so later in life

Nevus vasculosus often occurs on the scalp eyelids and in the eyebrows The hair follicles extend for a considerable distance below

the vascular new growth The nevus is extremely susceptible to the influence of the beta rays The beta rays are for the most part absorbed before they reach the hair bulbs For these reasons it is possible, with lightly screened radium and suberythema doses, to effect complete involution of the nevus without causing defluvium

Unless one has had considerable experience, it is not advisable to attempt the treatment of a nevus of large dimensions with tubular applicators, as the effect is likely to be very uneven If the growth happens to be linear, as may be the case on the eyelid, a tubular applicator may be of service It is advisable to protect the eye when treating a lesion of this kind on the eyelid This can be done by inserting a brass or lead eye shield under the lids

Wickham and Degrais, Newcomet, Finzi and many others have testified to the efficacy of radium in the treatment of nevus vasculosus The first articles written on this subject were from the pens of Danlos, Hartigan, Follard, Eckstein, Strasmann and Rehns (quoted by Wickham and Degrais)

Angioma Cavernosum.—In this type of angioma the deep vessels, especially the veins, are involved The lesions consist of soft tumors which vary in size from a pea to a silver dollar Occasionally they are much larger and may even involve the greater part of the face The tumor may project well above the surface of the skin or the elevation may be only slight The overlying skin may be normal, often it is the site of nevus vasculosus Not infrequently, lesions are encountered on the tongue, mucous surfaces of the cheeks, the labia, etc Cases are seen where the entire thickness of the cheek is involved in the growth Cavernous angiomata are found on nearly all parts of the body The sites of predilection are, perhaps, the face and scalp This type of nevus is exceedingly common in infants and children, less common in adults The explanation is that many such lesions undergo a slow spontaneous involution or are cured as a result of traumatism or ulceration or fibrosis

The fact that these lesions may spontaneously resolve makes it unwise to employ any method of treatment that might eventually terminate in objectionable sequelæ Spontaneous cure may be incomplete and exceedingly slow and it is often followed by a scar, fibrosis, atrophy, or an area that is much whiter than the surrounding normal skin The deeper lesions are likely to remain throughout life For these reasons treatment is indicated, but it should be associated with caution and good judgment

Small lesions can be totally eradicated by both x-rays and radium. Extensive and deep-seated lesions can be either eradicated or greatly improved There is no doubt but that beta rays are more efficacious than x-rays or gamma rays for exceedingly superficial lesions For deeper lesions gamma radiation has given the best results, thus far, better than those obtained with filtered x-rays.

Pfahler, Clark, Foerster, all the men mentioned in this chapter, and many others have obtained good results with radium Pusey and others have demonstrated satisfactory results with the *x*-rays Miescher reports excellent results in 562 cases He treats superficial lesions

Fig 248 —Nevus vasculosus of the upper right eyelid

with grenz rays and thorium X Deeper lesions are treated with both gamma rays and filtered *x*-rays Simons finds gamma rays superior He reports on 220 cavernous angiomas Oehlbeck believes that best results are obtained with filtered *x* rays Thus far our best results have been obtained with radium A squirming screaming child or infant can be treated better and more accurately with a radium applicator than with an *x* ray machine

Fig 249 —Same as Fig 248 after two radium treatments

A flat, glazed applicator, screened with 0 1 mm aluminum, will often produce excellent results when the lesion *involves only the upper* part of the true skin A half strength applicator, screened in this manner may be placed in contact with the lesion for ten fifteen or

twenty minutes, depending upon age, size and location. The applications are made every four or six weeks If there is no improvement after the first or second treatment gamma rays should be tried

Fig 250 —Small cavernous angioma before radium treatment.

As a rule, these lesions are very susceptible to radium therapy in infancy. The older the child the more treatment will be required, with less opportunity of attaining a perfect result The treatment is not effective in adults and adolescents and the outcome is doubtful in children over two years of age. While many physicians advise vigorous reactions, we advise against even first-degree reactions. They are unnecessary and may cause sequelæ.

Fig 251 —Same as Fig 250 after one radium treatment.

On the whole, and especially for large or deep-seated lesions, gamma rays are preferable. A tubular applicator containing 25 mg. radium element or 25 millicuries of radon, screened with 1 mm. brass, 0 5 mm silver and 1 mm Al, or with 0 5 mm. Pt at a distance of $\frac{1}{2}$ inch, is used for 1 square inch of skin surface. The exposure is two hours Double the amount of element or emanation reduces the exposure to one hour. A distance of 1 inch is preferable for very deep lesions

One half inch will suffice for the more superficial lesions The *dosage* is rather conservative and will suffice for the first application If there is no improvement in six or eight weeks a larger dose may be

FIG 252 — An extensive cavernous angioma involving the entire thickness of the cheek and the buccal mucosa

given Double this dose is frequently employed and many use even larger amounts If the area to be treated covers many square inches the dose should be smaller than for 1 square inch

Radon seeds may be used For this purpose the gold seeds are preferable and the dose should be very small—$\frac{1}{4}$ to $\frac{1}{2}$ mc radon per seed

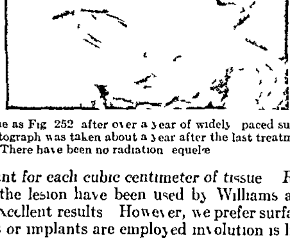

FIG 253 —Same as Fig 252 after over a year of widely spaced suberythema radium treatments Photograph was taken about a year after the last treatment This patient is now an adult There have been no radiation sequelae

and one implant for each cubic centimeter of tissue Radium needles inserted into the lesion have been used by Williams and Traub and others with excellent results However, we prefer surface treatments When needles or implants are employed involution is likely to be uneven

If x-rays are used they may be unfiltered or filtered with 3 mm. aluminum. Regardless of which agent is employed, reactions should be avoided. It is customary to inspect the patient each month after the treatment and not repeat the treatment so long as improvement continues. In some instances improvement continues for as long as six months after the first treatment.

In some locations, such as the cheeks and vulva, the lesion may be cross fired to advantage. Cavernous nevi situated on the scalp, when treated with x-rays or radium, may be followed by permanent alopecia. Usually, however, the dose is too small to cause loss of hair.

Fig. [illegible].—The deep and widespread angioma completely disappeared as a result of eight treatments with suberythema doses of radium over a period of fourteen months. The cosmetic result was excellent. The baby died of pneumonia before a final photograph was obtained.

The results sometimes obtained in this type of nevus are excellent. Photographs published by Simpson, by Wickham and Degrais, and others, depict results that are very satisfactory. We, years ago, treated a baby who had a facial cavernous angioma of such extent, irregularity and depth as to constitute a monstrosity. Treatment over a period of fourteen months with beta and gamma rays completely eradicated the nevus without visible injury to the skin. Several cases this type have been successfully treated.

We have found these angiomas radioresistant when involving

the mucous membranes It is in such cases that interstitial irradiation may be advantageous

The most important desideratum is to eradicate the nevus without causing the undesirable sequelæ that are so likely to be the result of strenuous treatment with x-rays or radium Many lesions will disappear as a result of one or two treatments Occasionally a number of treatments, extending over a year or more, are necessary If it is determined that a given angioma will not disappear without an amount of treatment that may seriously injure the skin it is advisable to discontinue the use of radiation In refractory, extensive or deep-seated cases it is often impossible to obtain complete involution without some visible atrophy In fact it is difficult in such instances to ascertain how much disfigurement is due to the former nevus and how much is due to the treatment While it may be impossible in some cases to avoid slight wrinkling of the skin it is possible to avoid telangiectasia and especially the more serious keratoses The operator should strive for good cosmetic results in all cases Almost every roentgenologist or radiologist can show a photograph of excellent results a few months or a year or two after treatment We hear less about the sequelæ that develop years later but we frequently encounter such cases in our private and clinic practice Figi, New and Dix, and other plastic surgeons call attention to disfiguring and serious late results of excessive treatment of angioma with x-rays and radium

Many physicians hesitate to recommend irradiation for angioma situated over the fontanels or over the epiphyses in such young children *These structures are not injured when the treatment is conservative* We have not had a single injury of this kind in our large number of patients many of whom have been seen twenty years or more after the treatment Kaplan and others have had similar experience We saw one patient who had atrophy of the muscles and bones of the thumb and index finger resulting from excessive dosage It is better to fail in a number of instances without doing harm than it is to cure several cases and have one patient with disfiguring and even dangerous sequelæ

LYMPHANGIOMA

We have not been able to modify the lesions of lymphangioma cavernosum in infants and children with either x-rays or radium externally applied Interstitial irradiation gives better results but even with such treatment the result is likely to be unsatisfactory Only 3 cases were treated, and it is possible that a wider experience might lead to the development of a technic that will give more encouraging results Gordon cured 1 case of lymphangioma of the tongue with radium Abbe cured 2 cases

Several cases of lymphangiectodes (lymphangioma circumscriptum) have been successfully treated with both x-rays and beta rays of radium, but they have not responded so quickly as have the vascular

nevi. The lesions were situated both on the skin and the buccal mucosa.

Abbe cured 6 cases with beta rays. McEwen reports improvement in one case treated with *x*-rays. Hartzell, Knowles, Ormsby, Simpson, Clark, and Engman and Mook have cured cases with *x*-rays. In one of Engman and Mook's patients the lesion occupied most of one side of the abdomen. Simpson reports the cure of a very large lesion with radium.

We have had better results with penetrating beta rays than with *x*-rays In all instances considerable treatment was required. The technic of application and precautions to be taken are the same as with vascular nevi and need not be repeated here.

Two cases of angiolymphangioma were successfully treated with radium. Dominici, Cheron and Barbarin cured an extensive case of hemolymphangioma with radium. The tumor occupied the right side of the neck and extended to the chest.

We do not recommend *x*-rays or radium for lymphangioma, hemangiolymphangioma or lymphangiectodes.

NEVUS PIGMENTOSUS.

Wickham and Degrais, Abbe, Simpson and others have removed pigmented nevi with beta rays of radium, and Pusey and others have accomplished the same results with *x*-rays.

We have given both agents a fair trial in nevus pigmentosus. There was no noteworthy amelioration unless the treatments were of sufficient strength to effect a sharp reaction and we are opposed to such treatment for pigmented nevi

X-rays and radium may be employed to depilate the hair in nevus pigmentosus et pilosus, and then some other method can be used to destroy the nevus (see under Nevus Pilosus), but we do not recommend such treatment.

It has been said that moles will disappear under the influence of radium treatment We have tried both beta rays and gamma rays without result. The doses used were within the amount necessary to evoke a first-degree reaction.

We are of the opinion that *x*-rays and radium are not indicated in the treatment of moles

NEVUS PILOSUS.

A growth of hair in a restricted area of skin that is usually free of hair may or may not be associated with pigmentation of the skin. In other words, we may have a nevus pilosus or a nevus pilosus et pigmentosus.

In the latter there is a difference of opinion as to whether the hair should be removed with radiation or with electrolysis Many dermatologists aver that the electrolytic needle should never be inserted into

a mole or any kind of pigmented nevus Others claim that there is more danger associated with irradiation than with electrolysis It is our opinion that the "needle" method is safe and that irradiation is dangerous We never employ irradiation for this purpose Technic is given in the Chapter on Hypertrichosis

ICHTHYOSIS AND CONGENITAL KERATODERMATA

The thickened horny layer of ichthyosis vulgaris ichthyosis hystrix, ichthyosiform erythroderma, etc will often shed after *x*-ray treatment The skin then has a normal appearance The benefit is of little value, however as in all cases so far treated there has been a recurrence within a few weeks

FIG 2?? —Ichthyosis before treatment

The same may be said regarding verrucous nevi congenital keratoderma palmaris et plantaris and keratosis pilaris In all cases treated by us the benefit has been but *temporary* *Allen treated cases of* verrucous nevus and, while he was able to improve the lesions, the results did not warrant advocacy of the method Wickham and Degrais, Simpson and others, report permanent cures in cases of linear verrucous *nevus and angiokeratoma* Wise treated 2 cases of linear verrucous nevus with unfiltered *x* rays but obtained no benefit We have been unable to cure verrucous nevi with *x*-rays or radium with doses that are unlikely to give rise to sequelæ

Monilethrix —Ciarrocchi claims to have cured 1 case of monilethrix with *x*-rays Low noted a disappearance of the associated keratosis pilaris and more normal hairs than before the *x*-ray treatment, but

the patient was not cured Guszman failed to obtain any improvement. We depilated two scalps of patients afflicted with monilethrix, with the same technic as used in tinea capitis. When the hair returned the beaded hairs appeared to be as numerous as before the treatment. The associated keratosis pilaris disappeared for a time, but it, too, returned.

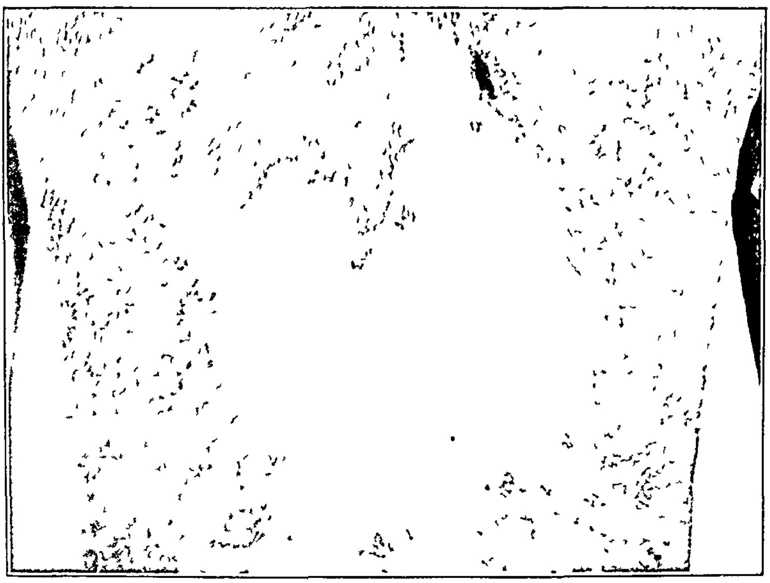

FIG 256—Same as Fig 255, showing exfoliation of thickened horny layer after one x-ray application Result is not permanent

Adenoma Sebaceum.—We treated 2 cases of adenoma sebaceum with beta rays of radium and 1 case with unfiltered x-rays There was no improvement Ormsby reports a similar experience.

Telangiectasia.—Telangiectasia may be congenital or acquired. These conditions, in our experience, cannot be eradicated with x-rays or radium without effecting unwarranted reactions. These statements apply, also, to the so-called spider nevus or nevus araneus. Much better results have been obtained with ultraviolet rays and the "electric needle"

We are acquainted with the reports in the literature of superb results in telangiectasia, regardless of cause, obtained with grenz rays, radon ointment, thorium X, radium element pad, alpha rays, etc Before recommending such treatment we desire to see not only the immediate result but the result several years later

BIBLIOGRAPHY

ABBE, R Lymphangioma and Radium, Med Rec, 88, 215, 1915
——— Radium Efficiency in Non-Malignant Surgical Conditions, Med Rec, 90, 47, 1916
AIKINS, W H B, and HARRISON, F C A Case of Nævus Linearis Treated by Radium, Urol and Cutan Rev, 27, 212, 1923

Allen C W in discussion on Gottheil W S Nævus Verrucosus Jour Cutan Dis 24 227 1906
Axmann H Beseitigung der durch Radiumstrahlen bewirkten Gefässerweiterungen München med Wchnschr 54 1877 1907
Ciarocchi G De l aplasie moniliforme des poils Ann de dermat et syph 4 s 1 1028 1900
Clark A S Radium in Dermatology Am Jour Med Sci 169 355 1925
Dominici H Chéron H and Barbarin Guérison d un hémo-lymphangiome profond des régions cervical et sus-claviculaire gauches par le radium Bull et mém Soc méd d hop de Paris 3 s 29 506 1910
Engman M F and Mook W H Lymphangioma Circumscriptum Recovery Under X Ray Treatment Jour Cutan Dis 31 266 1913
Figi F A New G B and Dix C R Radiodermatitis of the Head and Neck with a Discussion of Its Surgical Treatment Surg Gynec and Obst 77 254 1943
Finzi N S Radium Therapeutics London Henry Frowde Hodder & Stoughton 1913 p 72
Forster O H Radium in Dermatology Arch Dermat and Syph 9 38 1924
Hartzell M B in discussion on Engman M S and Mook W H Lymphangioma Circumscriptum Recovery under X Ray Treatment Jour Cutan Dis 31 267 1913
——— in discussion on Harris Lymphangioma Circumscriptum Jour Cutan Dis 33 402 1915
Kaplan I I *Hemangioma of the Elbow Successfully Treated with Radium at an Early Age* Am Jour Dis Child 65 785 1943
Low R C The Pathology and Etiology of Monilethrix Jour Path and Bacteriol 14 230 1909 1910
McEwen L L Lymphangiectodes Jour Cutan Dis 28 264 1910
Miescher G Die Strahlentherapie der Angiome Schweiz med Wchnschr 73 1247 1943
New G B Radium in the Treatment of Lymphangioma of the Tongue Journal Lancet 36 609 1916 Abstract Radium 9 15 1917
Newcomet W S The Treatment of Nevi Am Jour Roentgenol 4 605 (Jan) 1917
——— Radium and Radiotherapy Philadelphia Lea & Febiger 1914 p 272
Oehlbeck L W Roentgen Rays in Treatment of Nonmalignant Disease North Carolina Med Jour 5 81 1944
Ormsby O S in discussion on Engman M F and Mook W H Lymphangioma Circumscriptum Recovery under X Ray Treatment Jour Cutan Dis 31 267 1913
——— Adenoma Sebaceum Jour Cutan Dis 35 48 1917
Pusey W A Roentgen Therapeutics of Superficial Lesions Am Jour Roentgenol 2 613 1914–1915
Simons Albert Radium Treatment of Hemangiomas Acta med orient 2 192 1943
Simpson F E Radium in Skin Diseases Jour Am Med Assn 61 80 1913
——— Radium in the Treatment of Lymphangioma Circumscriptum Report of a Case Jour Am Med Assn 66 949 1916 Abstract Radium 7 77 1916
——— Radium in the Treatment of Cancer and Various Other Diseases of the Skin Jour Am Med Assn 67 1508 1916
——— Radium Therapy St Louis The C V Mosby Company 1922 p 273
Wickham L and Degrais P Radiumtherapy Translated by S Ernest Doré London Cassell & Co 1910 p 181

CHAPTER XXXVIII.

BENIGN NEW GROWTHS.

MANY diseases classified pathologically as benign new growths will be found discussed in other chapters. Some of the growths in this chapter are granulomata. The grouping used here is a convenient grouping rather than a scientific classification. The entities discussed in this chapter are:

1. Keloid.
2. Dermatitis Papillaris Capillitii.
3. Rhinoscleroma.
4. Xanthoma.
5. Fibroma; Neuroma; Myoma.
6. Lipoma
7. Multiple Benign Cystic Epithelioma and Allied Conditions.
8. Leprosy
9. Syphilis
10. Ulcerating Granuloma of the Pudenda (Granuloma Inguinale).
11. Lymphogranulomatosis Inguinalis (Lymphopathia Venereum).

KELOID.

Ullmann, Albers-Schonberg, Morton, Pusey, and Allen were the first to report the usefulness of *x*-rays in the treatment of keloids and hypertrophic scars Ullmann noted the improvement in scar tissue while treating lupus vulgaris and suggested that the *x*-rays be tried in keloidal tissue from other causes.

Williams was the first to employ radium for this purpose. Wickham and Degrais a few months later reported the successful treatment of a number of cases.

Today there is a pretty general agreement that irradiation alone in most cases, and combined with surgery in some cases, constitutes the best method of combating keloid and hypertrophic scar. It is the only method of treatment that insures against recurrence.

Clinical Types.—Dermatologists recognize two types of keloid: True spontaneous, or idiopathic, keloid and keloid that develops in a scar. The latter are called hypertrophic scars. Inasmuch as the effect of irradiation is the same in both types, it is not necessary to discuss them separately.

Keloids may range from a slight thickening of scar tissue to great tumors the size of an adult male fist and even larger. They may

consist of a well-defined tumor arising from a tiny scar or they may be spread over very large surfaces as is so frequently seen in keloids following burns There may be keloidal bands which cause disfigurement by displacing the soft parts such as the mouth, eyelids, etc

Fig 257 — A very dense and long standing keloid resulting from an electric burn

Keloids may be red, brown or the color of normal skin Often they are telangiectatic At times they are pedunculated They may be sensitive to pressure Keloids that have existed for a long time and keloids that have evolved very slowly are likely to be firm even hard Recent keloids and those of comparatively rapid growth are much less hard to the palpating finger

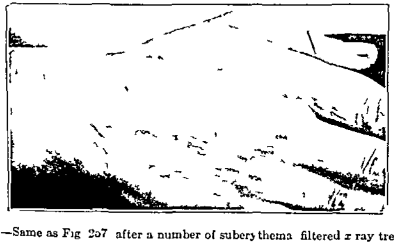

Fig 258 —Same as Fig 257 after a number of suberythema filtered x ray treatments

These facts are of importance to the roentgenologist Young small, vascular rapidly growing keloids resolve fairly rapidly when irradiated Larger growths, older growths and those that evolve very slowly may be recalcitrant The other manifestations such as erythema, pain and telangiectasia, will be discussed later

Comparison of Irradiation with Other Methods.—Surgery does not give good results as a rule because recurrence is common and the recurrence is likely to be much worse than the original growth. Solid carbon dioxide has many advocates, especially for small keloids. Electrolysis, cauterization and other measures have been recommended for selected cases. However, any method of treatment that produces a wound, *i. e.*, that is traumatic, is likely to be followed by a keloid that is larger than the one removed, with the exception of solid carbon dioxide. Irradiation is the only known method of treatment that will positively preclude recurrence. The cosmetic result is better, as a rule, after irradiation than after other forms of treatment but this is not always so.

FIG. 259.—Keloid following operation.

FIG. 260.—Same as Fig. 259, after six suberythema, unfiltered x-ray treatments.

Prophylactic Treatment.—Keloids occur mostly in persons who are idiosyncratic, *i. e.*, persons who have a keloidal tendency. Years ago we were of the opinion that the irradiation of a healed wound occurring in an idiosyncratic person would prevent the subsequent development of keloid. It has, however, been necessary to modify this opinion. That a keloid may develop in tissue that has been irradiated is shown by the following cases:

CASE 1.—A young woman had an epithelioma (basal-cell type) situated in the nasolabial fold. The tumor was given four strong x-ray treatments without favorable results. It was then removed with the curette and acid

nitrate of mercury was applied to the floor of the wound for fifteen minutes The resulting crust did not fall off for two months at which time there appeared a rapidly growing keloid the diagnosis of which was confirmed by a biopsy *The keloid disappeared as a result of two suberythema doses of x rays* There has been no recurrence of either the epithelioma or of the keloid during a period of thirty years

Case 2—*An attempt had been made to remove, with x-rays,* a mole from the chin of a woman of middle age After three treatments the lesion was excised The excision was followed by a keloid which also was excised *A recurrence took place* The new keloid was treated successfully with *x* rays There has been no recurrence

Case 3—A young woman had received *x* ray treatment in Germany for lupus vulgaris of the left cheek *When seen by us there was no evidence of lupus*, but there were numerous *x* ray sequelæ—atrophy, telangiectasia and keratoses Part of the ear was keloidal

Fig 361—Keloid of mucous membrane of lip before radium treatment.

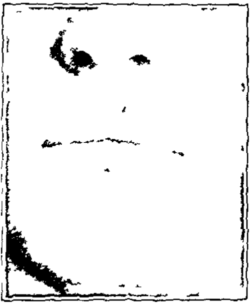

Fig 362—Same as Fig 361 after radium treatment

Case 4—A girl of 12 had large thick keloids on the chest which followed scalding with hot water One keloid was removed to the level of the skin surgically Subsequent irradiation *failed to prevent immediate recurrence* A smaller keloid was then excised This was followed by primary healing and a keloid larger than the original lesion in spite of pre-surgical and post surgical irradiation Later a large keloid was removed by plastic surgery Keloids developed at the site of the original lesion and in areas where skin was removed for grafting in spite of *x*-ray treatment *Several years later this patient ran a high temperature for several days The idiosyncrasy disappeared either spontaneously or because of the fever Subsequent surgery was successful* without irradiation

Newcomet reports the development *of a large keloid following the very vigorous application of radium to a port-wine mark*

While it must be *admitted that irradiation is not a true prophylac-*

tic against the development of keloid, it is nevertheless of value for this purpose if employed at the proper time. When removing keloids by excision Pfahler recommends the administration of a suberythema dose just prior to the operation and additional treatment at the slightest evidence of recurrence. Levitt and Gillies recommend similar treatment. Nason prefers irradiation in from three to five days after excision Costello agrees with most if not all of our opinions as expressed in this chapter. Hunter, after twenty years experience, is undecided how best to employ *x*-rays as a prophylactic measure. He has obtained satisfactory results in a series of 931 patients. Preliminary treatment may be of value when a keloid is already present, but it is doubtful if such preliminary treatment would prevent the evolution of a keloid subsequent to trauma occurring in an idiosyncratic person. In fact, we doubt the value of preliminary irradiation, even when a keloid is to be excised, excepting for the purpose of promoting the involution of keloidal tissues that may escape the knife.

Pfahler scores a good point when he advocates the early diagnosis and irradiation of keloid. If surgeons would recognize hypertrophy of scar tissue as soon as clinically manifest and have the area irradiated at once, it might not require more than one or two suberythema applications to prevent further development and to cause the disappearance of the infiltration.

It is doubtful if a single treatment with *x*-rays or radium, subsequent to traumatism, but prior to clinical thickening of the scar, would prove of value in preventing keloid. Furthermore, there is no certainty that a keloid will return after excision, or that it will develop after traumatism in an idiosyncratic person. The best prophylactic procedure, therefore, seems to be to watch for the very first manifestation of keloidal evolution. One, two or three suberythema doses of either *x*-rays or radium or weekly treatment over a period of a few weeks may prevent further development and cause involution of the slight clinical thickening of the scar. However, many physicians prefer to apply suberythema doses once monthly for a few months as a preventive. It is possible that such treatment might prevent the thickening and spreading of scar tissue due to tension. While postoperative irradiation often will prevent recurrence of a keloid, it will not always do so.

Combined Treatment.—Thick keloids cannot be removed by irradiation without danger of leaving undesirable and even serious sequelæ. Such keloids should be removed by the knife or by the cutting current, and irradiation employed as a prophylactic. As pointed out by Pfahler, it is not necessary to make a wide excision; endeavor to obtain a good cosmetic result; it does not matter if keloidal tissue is left *in situ.* When the growth is situated in an inaccessible location it may be possible to do no more than to cut away the bulk of the mass, the wound being allowed to granulate. At times it is advisable to remove only the portion of the keloid that is above the skin level. As men-

tioned above Pfahler recommends a preliminary suberythema dose After the operation, if keloidal tissue has been left *in situ*, monthly suberythema exposures or weekly exposures are made for three or four months If the excision has been complete the patient should be kept under observation and irradiation delayed until there is clinical evidence of thickening, when a few suberythema applications will often suffice for the desired result

Sequelæ.—It is uncommon to have a well-developed keloid resolve without leaving a cosmetic defect This defect may consist of a scar, more or less atrophy and perhaps telangiectasia We are not discussing *x* ray and radium sequelæ It should be appreciated that these defects are caused by the disease—not by the treatment Of course, irradiation can effect the same sequelæ—atrophy telangiectasia, depigmentation, etc

Results—The results of irradiation in most types of keloid are gratifying Small keloids (split-pea to dime) will often disappear as a result of a few suberythema treatments with little if any disfigurement, especially if they have existed for only a few months One must not expect to have large and older keloids disappear without leaving some scarring or atrophy and perhaps a few dilated vessels Furthermore, such keloids require considerably more treatment Growths the size of a silver dollar, or the palm of a hand may require as many as eight ten or twelve suberythema treatments over a period of a year or more This of course, will depend upon the thickness and hardness of the growth A widespread but not thick keloid, one, for instance, that occupies the entire chest, will often flatten to the level of the skin when properly irradiated On the other hand, quarter to palm-sized tumors that are from ½ to 1 inch or more in thickness may not disappear under an amount of radiation that is within the limits of safety Such tumors may be excised surgically or with the cutting current and irradiation employed as a prophylactic

Keloidal bands, irregular keloidal masses scattered over an extensive surface and old hard keloids even when only slightly elevated are very unyielding and good judgment and considerable caution is required in order to avoid disfiguring and dangerous sequelæ

The erythema that is associated with some keloids may or may not disappear during the treatment Usually it does not disappear until several months after the last treatment Pain, if present often disappears after the first few treatments

After involution of a keloid subsequent to irradiation the skin or the scar is usually soft and pliable Contractions (ectropion, etc) are therefore prevented

There are many keloids and hypertrophic scars, even small ones, that refuse to improve at all as a result of irradiation It is partly for this reason, as well as for reasons that will be given later that it is inadvisable to give more treatment than is absolutely safe Also, it

[illegible]

[illegible] the skin should [illegible] for evidence of injury.

[illegible] be employed for prophylactic treatment [illegible] are not of long duration and for widespread [illegible] are only slightly elevated. [illegible] however the [illegible] screened with 1 mm. of aluminum.

Radium. [illegible] the view of Simpson and others, [illegible] that radium is superior to x-rays in the treatment of keloid. Knox, who had the opportunity of treating many keloidal scars [illegible] World War, does not mention any difference in the [illegible] his results in the use of both of these [illegible] surgery of the face following gunshot wounds [illegible]. We have failed to note any difference in efficacy between [illegible]. Hypertrophic scars or keloids, when the pathology is only 1 or 2 mm. in thickness, seem to do better under [illegible] treatment.

Radium is more easily applied to lesions in locations where it would be difficult to administer x-rays. In some instances it is possible to [illegible] with a combination of x-rays and radium. Knox used this method to good advantage in the extensive and deep-seated keloidal masses developing in the cheeks. Radium was placed in the mouth and x-rays were applied to the external surface of the cheek.

Flat radium applicators are usually employed when treating keloid with radium. In all cases the "soft" beta rays should be eliminated by suitable screening. If the lesion is more than 1 or 2 mm. thick only gamma rays should be used. In general, the advice given relative to the x-ray treatment of keloid holds for radium when used for the same purpose. A half-strength, glazed, flat element applicator, screened with 0.1 mm. aluminum, may be placed in contact with the keloid for ten, fifteen or twenty minutes, depending on size, age and location. Treatments may be repeated about once monthly. Such applications are suitable for superficial lesions. Gamma rays are employed for

thick, hard lesions The flat applicator (half-strength) may be screened with 1 mm brass and 1 mm Al and placed in contact with the lesion for eight to twelve hours This may be done at one time or one or two hours daily Tubular applicators, containing 25 mg element, or 25 millicuries radon and screened with 1 mm brass, 0 5 mm silver and 1 mm Al or 0 5 mm Pt and placed at a distance of ½ or 1 inch, may be held over each square inch of surface for from two to six hours

DERMATITIS PAPILLARIS CAPILLITII

There are but few references in the literature relative to the treatment of this disease with *x*-rays Most of the books on roentgen therapy and radium therapy fail even to mention the disease On the other hand, practically all of the dermatologic textbooks recommend the use of *x*-rays, stating that the progress of the disease can be checked and the keloidal scars reduced in size G H Fox was apparently the first to use *x* rays in this condition while Wickham and Degrais were the first to treat the disease with radium

Dermatitis papillaris capillitii (acne keloid) is usually situated on the back of the neck—the nucha In the early stage of evolution the eruption consists of extremely hard pinhead-sized papules which are situated in the follicular orifices There are occasional pustules The hairs are twisted, dry and break readily At first the elementary lesions are discrete later they become closely aggregated and finally they coalesce into keloidal masses that may range in size from a split pea to a walnut and even the size of an adult male fist The evolution is slow, it is usually several years before the keloidal lesions become very large

If the disease is irradiated during the papular stage it may be aborted and permanently eradicated as a result of from one to three sub erythema applications at monthly intervals The back of the neck in adults will usually tolerate 225 r without provoking an erythema The same results will follow weekly and semi monthly treatments Unfiltered radiation is suitable for the early stage

After the advent of the keloidal stage the disease is more stubborn the degree of resistance depending upon the duration and size of the keloidal tumors In this stage filtered radiation is indicated and the technic does not differ from that given for keloids Large tumors may be excised or reduced in size by some other method and radiation applied to effect complete involution and to eradicate the disease

The disease itself destroys most of the hair follicles This should not be blamed on the treatment

The disease may occupy the entire nucha and may involve the lateral surfaces of the neck This constitutes a large convex surface which requires two exposures one for each side, care being taken not to allow overlapping in the center All parts not affected by the disease should be shielded, special attention being given to the scalp hair

Radium.—The results of radium treatment are the same as those obtained with the *x*-rays In the early stage "hard" beta rays are employed, the "soft" beta rays being eliminated by means of a

Fig 263.—*Dermatitis papillaris capillitii* Before treatment.

screen of 0.1 mm of aluminum. Thick keloidal masses should be treated with gamma rays. Gamma-ray treatment is the same as described under Keloid.

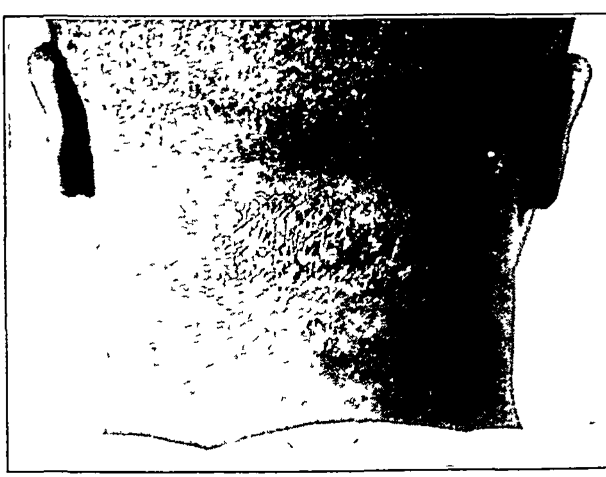

Fig 264 —Same as Fig 263, after *x*-ray treatment

The points to be emphasized in the treatment of this condition are

1. Early diagnosis and early institution of roentgen therapy or radium therapy.
2. Avoid even first-degree reactions.
3. In order to avoid long-continued treatment with the possibility of undesirable sequelæ, it is often advisable first to treat large keloidal

masses with some surgical method and then irradiate for the purpose of thoroughly eradicating the disease

Fig 265 —Large keloid before treatment

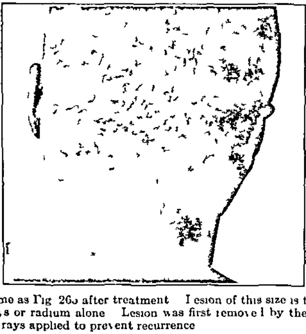

Fig 266 —Same as Fig 265 after treatment Lesion of this size is too large for good result with x rays or radium alone Lesion was first removed by the cutting current and unfiltered x rays applied to prevent recurrence

We have never seen or heard of a recurrence after a clinical cure Irradiation gives better results than can be obtained with any other method Such treatment may be depended upon to cure most cases but it is by no means always successful

RHINOSCLEROMA.

This annoying and heretofore intractable disease can be permanently cured with *x*-rays or radium. In the early granulomatous stage the condition yields satisfactorily to treatment. In the later stage, when the nose is greatly enlarged and the tissue is stonelike in consistence, the disease is more stubborn.

Ranzi, in 1904, appears to have been the first to establish a literary record of the *x*-ray treatment of this disease This author, however refers to 2 cases that were treated by Fittig. Pollitzer presented a cured case before the New York Academy of Medicine, Section on Laryngology, in October, 1906. Ballin reported a cured case in 1907, the *x*-rays having been applied by Stern Lustgarten presented the patient before the New York Dermatological Society (April, 1907), at which time he told of the good results obtained in additional cases treated by Stern Many of the earlier roentgenologists reported successful results with *x*-rays in the treatment of single examples of this disease

Wunderlich, of Guatemala, has had considerable experience with the *x*-ray treatment of rhinoscleroma. He presented 3 cured cases before the Pan-American Medical Congress in 1908 and later reported 14 additional cures

Kahler was apparently the first to treat rhinoscleroma with radium (1905) Guttman and others report great improvement in cases treated with radium

We have cured 3 cases of rhinoscleroma with *x*-rays In one instance the disease was diagnosed in a very early stage The lesion consisted of a firm but not hard tumor occupying the right nostril. The patient was cured as a result of three monthly suberythema treatments In 2 patients the disease was well developed, the nose being greatly enlarged and the disease involved the upper lip The affected parts were as hard as rock and the nasal passage was completely occluded Both patients were cured, the parts returning to normal, as a result of five monthly suberythema treatments in 1 case and eight such treatments in the other In each instance the diagnosis was confirmed by biopsy Two additional cases were treated with considerable improvement, but the patients failed to continue the treatment or to remain under observation.

There have been no reports of recurrence subsequent to a complete clinical cure The result appears to be permanent Irradiation alone will cure the condition, but it is advisable to employ, also, vaccine therapy

Technic.—It is advisable to have the patient carefully examined by a competent rhinologist in order to ascertain the extent of involvement. Usually the disease begins in the mucous membrane of the anterior nares It may then involve the entire nose and the upper lip. Rarely the disease may develop in the larynx, as was the case in one of Lust-

garten's patients who was treated by Stern After the first x ray treatment the dyspnea became so great that it was necessary to open

Fig 267 —Rhinoscleroma (Courtesy of Dr M J Wunderlich)

Fig 268 — Same as Fig 267 after roentgen ray treatment (Courtesy of Dr M J Wunderlich)

Fig 269 —Rhinoscleroma (Courtesy of Dr M J Wunderlich)

Fig 270 —Same as Fig 269 after x ray treatment (Courtesy of Dr M J Wunderlich)

both the larynx and trachea When the report was made the tumor had disappeared

As a rule, then, the treatment can be confined to the nose and upper lip, if the latter is involved.

The aim should be to cure the disease without leaving sequelæ and in the majority of cases this is possible. Only filtered radiation should be employed (3 mm Al). The dose should be within the amount required to effect an erythema—about 400 r, depending upon the age of the patient and the color of the skin. Applications are made at intervals of one month. The entire face, with the exception of the nose, is shielded. An exposure is then made to each side of the nose with the target at right angles to a plane of the lateral surface of the nose. The rays are permitted to overlap at the bridge of the nose. A separate exposure may be necessary for the upper lip if this part is involved.

If the nares are patulous a tubular radium applicator, suitably screened, may be placed inside the nose, first in one nostril and then in the other. The length of exposure will depend, naturally, upon the amount of radium element in the tube. A 25-mg. tube, screened with 1 mm brass, 0.5 mm. silver and 1 mm. Al, may be left in the nose for two or three hours, in addition to the *x*-ray treatment applied to the external surface of the nose. If the nares are occluded the radium (tube or plaque), suitably screened, may be placed against the the roof of the mouth. These cross-fire treatments, in the absence of reaction, may be administered at intervals of one month.

Gamma rays of radium may be used instead of *x*-rays for the external irradiation. The result should be the same. The technic is about the same as that described for keloid, in this chapter.

XANTHOMA.

The author applied suberythema doses of *x*-rays to several lesions in 1 case of xanthoma tuberosum, 1 of xanthoma planum and 1 of xanthoma diabeticorum. In the first patient treated (xanthoma tuberosum) there was some involution of the irradiated lesions after the first suberythema treatment. There was no improvement after the second and third exposures. The lesions in the other patients did not improve at all. Beta rays of radium were applied to the lesions in 1 case of xanthelasma (xanthoma palpebrarum). There was no improvement as a result of three suberythema applications of "hard" beta rays. Applications of a strength sufficient to effect a reaction were not tried, such treatment is not justified.

Gottheil tried *x*-ray treatment in a case of xanthoma tuberosum multiplex with negative results. Brown obtained benefit in 2 cases after a reaction had been produced. Allen, Evans and other early workers report good results in the various types of xanthoma. It should be realized that these reports were made years ago, when roentgenologists did not appreciate the advisability of avoiding *x*-ray sequelæ. Pinch treated 7 cases with radium; 5 patients were cured;

2 patients were improved Williams presented, before the New York Dermatological Society, a case of xanthoma with a very young, generalized eruption, that was greatly benefited by x ray treatment These are old references In recent years there have been few if any reports on this subject We do not treat any variety of xanthoma with radiation

FIG 271 —Benign cystic epithelioma or syringoma before x ray treatment

FIG 272 —Same as Fig 271 after x ray treatment A great deal of treatment was necessary and on one or two occasions there was a first-degree reaction The immediate result was excellent but years later the patient developed x ray skin

FIBROMA, NEUROMA, MYOMA, LIPOMA

Schlutz, Bondet and others state that x-rays will sometimes cause a diminution in the size of cutaneous lipomata, fibromata and allied conditions The necessity of effecting a reaction is admitted In our hands the results have not been favorable

As is well known uterine fibromas and myomas undergo complete involution when irradiated It is however, the consensus that the result is caused by the effect of the radiation on the ovaries and not by direct action on the tumor

Wise treated a hazel-nut sized tumor of fibroma molluscum (von Recklinghausen's disease) Three unfiltered suberythema doses were applied at intervals of four weeks There was no alteration in the size or consistence of the tumor (verbal communication)

BENIGN EPITHELIOMA.

We have tried x-ray treatment in cases of benign cystic epithelioma, tricho-epithelioma, syringoma and allied conditions. It is possible to cause complete involution of the lesions, but to do so it is necessary to effect at least a first-degree reaction which is inadvisable.

Mitsuto caused complete disappearance of an eruption of syringoma situated on the chest with four x-ray treatments, each application consisting of one-third of an erythema dose. Ormsby and others cured a case of syringoma with weekly x-ray treatments. In spite of occasional good results we do not recommend irradiation for these diseases.

LEPROSY.

Heiser treated one leprosy patient with x-rays. All clinical evidence of the disease disappeared, but lepra bacilli could be found in scrapings from the nasal mucosa. Allen, Morris and others have noted improvement in lesions that have been subjected to irradiation. Neil and Sandidge, of the Kaliki Leper Receiving Hospital, of Honolulu, made intranasal applications of radium to patients who had nasal lesions. The lesions disappeared and lepra bacilli disappeared from the nasal secretion.

We have administered x-ray treatment to 8 cases of leprosy of different clinical types. In no case was there more than partial involution of the lesions. Irradiation appears to be of little, if any, value in this disease.

SYPHILIS.

The older textbooks and journals contain numerous references to the use of x-rays in syphilis. Cowen, for instance, exposed the entire body of a patient affected with tertiary syphilis to radiation. According to Cowen's article, the results were remarkable. Of course, irradiation is not of the slightest service in the treatment of syphilis, and is only employed in this disease when there has been a mistake in diagnosis Syphilitic lesions, even ulcerated lesions, are very resistant to irradiation. In former years it was thought that involution could be hastened in this manner. Most cutaneous lesions of syphilis undergo spontaneous involution in time This fact, together with the fact that involution was often slow under the older methods of antisyphilitic treatment, probably explains the reason for the opinions of some roentgenologists of former years.

Gangosa.—No record can be found relating to the use of radium or x-rays in the treatment of gangosa Mink and McLean, who have made a careful study of the disease, suggest irradiation but they have not tried such treatment nor have they heard of its having been employed for this purpose.

Ulcerating Granuloma of the Pudenda (Granuloma Inguinale).—Macleod has employed roentgen therapy with success in this disease.

Most of the older English textbooks on dermatology recommend roentgenization. Several articles dealing exhaustively with this disease have been consulted, but practically nothing has been found to prove the usefulness of irradiation in this disease.

Lymphogranulomatosis Inguinalis (Lymphopathia Venereum).—Most modern textbooks and many recent articles state that x rays are useful in this disease. Martin and de Lorimier, in a recent article, report on 61 cases of this disease treated with x-rays. They had uniformly good results. Better results have been reported with the sulfonamides, but x rays may be useful when these drugs can not be used. There has been no personal experience.

BIBLIOGRAPHY

ABBE R Radium Efficiency in Non Malignant Surgical Conditions Med Rec 90 47 1916

ALBERS-SCHONBERG and HAHN R Die Therapie des Lupus und der Hautkrankheiten mittels Rontgenstrahlen Munchen med Wchnschr 47 284 325 363 1900

ALLEN C W Radiotherapy and Phototherapy Philadelphia Lea & Febiger 1904 pp 244 288

BALLIN M J A Case of Rhinoscleroma Treated With the X ray New York Med Jour 85 490 190

BONDET Traitement des Lipomes par les rayons X Lyon méd 103 223 1904

BROWN W B Two Cases of Xanthoma Multiplex Jour Cutan Dis 23 318 1905

COSTELLO M J Keloids and Their Treatment Med Rec 154 205 1941

COWEN R J X rays in Tertiary Syphilis Am J Dermat and Genito urin Dis 9 420 1905

FITTIG Quoted by Ranzi [Demon triert einem gunstigen Rontgenerfolg bei Rhino sclerom] (Discussion) Fortschr a d Geb d Rontgenstrahlen 8 284 1904–1905

GOTTHEIL W S Rhinoscleroma Jour Cutan Dis 24 37 1906

GUTTMAN J Radium in Rhinoscleroma New York Med Jour 102 711 1915

HEISER V G Preliminary Notes Upon a Case of Leprosy Apparently Cured With the X rays Med Rec 74 757 1908

HUNTER A F Roentgen Therapy of Hypertrophic Scars and Keloids Radiology 39 400 1941

KNOX R Radiography and Radiotherapeutics London A and C Black Ltd 2d ed 1917 p 562

MACLEOD J M H Discussion Concerning the X ray Treatment of Granuloma Tropicum Brit Jour Dermat 25 66 1913

MARTIN J I and DE LORIMIER A A Roentgen Therapy in Lymphogranuloma Venereum Am Jour Roentgenol 42 376 1939

MINK O J and MCLEAN N T Gangosa With Additional Notes Jour Cutan Dis 25 503 1907

MORRIS M A Case of Leprosy Treated With a Special Vaccine Proc Roy Soc Med S Dermat 2 41 1908 A Case of Rodent Ulcer Ibid 2 45 1908

MORTON W J Artificial Fluorescence of Living Human Tissue Med Rec 64 215 1903

——— Primary and Recurrent Mammary Carcinoma Treated by the X ray ibid 63 845 1903

——— Some Cases Treated by the X ray Facial Cancer Carbuncle Cheloid Acne Alopecia Areata Sycho is Fibroid Tumor Psoriasis and Lupus ibid 64 121 1903

——— Primary and Recurrent Mammary Carcinoma Treated by the X ray ibid 63 845 1903 Some Cases Treated by the X ray Facial Cancer Carbuncle Cheloid Acne Alopecia Areata Sychosis Fibroid Tumor Psoriasis and Lupus ibid 64 121 1903

NEWCOMET W S The Treatment of Nevi Am Jour Roentgenol 4 605 (Jan) 1917

OULMANN L Lepra Tuberosa Jour Cutan Dis 25 373 1907

PFAHLER, G E. Roentgen Rays or Radium Combined With Excision in the Treatment of Keloids, Arch Dermat and Syph, 2, 181, 1920

PINCH, A E H. A Report of the Work Carried Out at the Radium Institute, London, from January 1 to December 31, 1917, Radium, 11, 49, 1918, 13, 65, 1919, 15, 69, 1920

POLLITZER, S Rhinoscleroma Cured by X-ray Treatment, Jour Cutan Dis, 28, 388, 1910

PUSEY, W A, and CALDWELL, E W The Practical Application of the Rontgen Rays in Therapeutics and Diagnosis, 2d ed, Philadelphia, W B Saunders Company, 1904, p 647

RANZI [Demonstriert einem gunstigen Rontgenerfolg bei Rhinosclerom] (Discussion), Fortschr a d Geb d Rontgenstrahlen, 8, 284, 1904–1905

SCHULTZ, F X-ray Treatment of Skin Diseases, Translated by James Burnet, New York, Rebman Company, 1912, p 141

SIMPSON, F E Radium in the Treatment of Keloids, Jour Am Med Assn, 64, 1300, 1915

ULLMANN, C Der Einfluss des Lichtes auf die gesunde und kranke Haut, Wien med Presse, 41, 951, 1900

WICKHAM, L, and DEGRAIS, P Radiumtherapy, Translated by S Ernest Doré, London, Cassell & Co, 1910, pp 160, 172

WILLIAMS Quoted by Wickham, L, and Degrais, P Radiumtherapy, London, Cassell & Co, 1910, p 160

WUNDERLICH, M J Quoted by MacKee, G M, Rhinoscleroma and the Roentgen Ray, Am Jour Roentgenol, 4, 181, 1917

CHAPTER XXXIX

MALIGNANT NEW GROWTHS

The cutaneous new growths discussed in this chapter are

1 Basal-Cell Epithelioma
2 Basal-Squamous Cell Epithelioma
3 Prickle-Cell (Squamous-Cell) Epithelioma
4 Metastatic Carcinoma of the Skin
5 Paget's Disease
6 Bowen's Disease
7 Melanocarcinoma
8 Sarcoma
    Round-Cell Sarcoma
    Spindle-Cell Sarcoma
    Fibrosarcoma
9 Kaposi Sarcoma—Idiopathic Multiple Hemorrhagic Sarcoma of Kaposi

BASAL-CELL EPITHELIOMA

The first basal-cell epithelioma to be treated with x rays was demonstrated before the Swedish Medical Society on December 18, 1899, by Stenbeck, of Stockholm At the same meeting Sjogren showed a similar case In the former instance however, the epithelioma had disappeared, while in the latter the demonstration occurred before a clinical cure had been effected These reports were immediately followed by others and very soon the literature was swamped with articles on this subject The earliest reports in Europe were from the pens of Sederholm, Scholtz, Taylor, Ferguson and Sequeira In the United States the earliest workers were Johnson and Merrill, Pusey, Williams, Beck, Rinehart, Morton, Hopkins, Allen, and Duncan

Statistics —In the past twenty years a voluminous literature dealing with roentgen therapy in basal cell epithelioma has been developed But before reviewing and commenting on the more important articles we desire to relate the results obtained in 644 unselected cases of basal-cell epithelioma which were treated by the senior author between the years 1910 and 1919 inclusive Dosage ranged from 300 r to 1200 r, usually 600 r administered at one sitting During this period dosages were determined with pastilles and skin effects From one to four erythema doses were applied at one sitting

Clinical Cures —Of the 644 patients 183 were not seen after the first treatment so that the result could not be recorded This leaves a total of 461 patients who remained under observation for at least a few months Of these 461 cases there were 421 clinical cures, or

91 per cent. Thirty-three patients, 7 per cent, improved, and in 7 cases, 2 per cent, the lesions were not even benefited. When it is considered that the cases were not selected and that at least one-half the failures were due to the patients' inability to have second or third treatments at proper intervals, or that the case was deemed practically hopeless when treatment was instituted, 91 per cent seems very satisfactory. As an illustration, several of the patients received a single treatment which did not suffice to effect a clinical cure. Then, on account of illness, old age, stormy weather, or other reasons, they did not return for the second treatment until the lesion was worse than it was at the beginning. In other instances the lesions were very deep and indurated, even involving the articulations or the entire orbit, and had received previous roentgen-ray treatment. If one could omit such cases the percentage of cures would be in the neighborhood of 96 or 98 instead of 91

Fig 273 —Ulcero-nodular basal-cell epithelioma

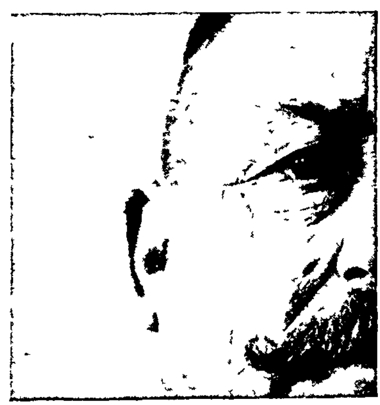

Fig 274 —Same as Fig 273, after two strong x-ray treatments No recurrence after fifteen years

Preepitheliomatous lesions are not included in this study. In other words, every case was distinctly an epithelioma from a clinical standpoint and the lesions varied in size from a split-pea to several inches in diameter, in duration from a few months to several years, and they either developed as a nodule or evolved from some preepitheliomatous lesion In only a few cases was the diagnosis confirmed by the microscope, but in most instances the patients were seen by dermatologic confrères who agreed with the diagnosis.

Recurrences.—Of the 421 clinically cured cases, 139 failed to remain under observation for six months. As will be seen later, most of the recurrences take place within one year so that patients that are not observed for at least six months are of little statistical value as far as the question of recurrence is concerned We have, then, a total of 282 clinically cured cases that were observed for periods of from six months to nine or more years. In this series of 282 cases there were 36 relapses —13 per cent. leaving a total of possible permanent cures of 87 per cent.

Late Recurrence.—It is interesting to note that a majority of the recurrences manifested themselves in less than a year.

The fact that one relapse was noted as late as the fourth year makes it advisable to warn the patient of this possibility. That there is not much like

Fig. 275.—Basal-cell epithelioma on the right side of the bridge of the nose.

Fig. 276.—Same as Fig. 275 after unfiltered x-ray therapy. The patient received 300 r every other day for a total of eight treatments.

lihood of a recedive after the fourth year in properly treated cases is shown by the fact that 102 patients were observed for periods of from four to nine years and yet there was only 1 relapse that manifested itself four years after

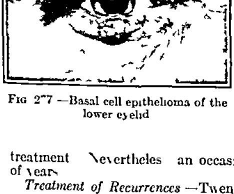

Fig. 277.—Basal cell epithelioma of the lower eyelid.

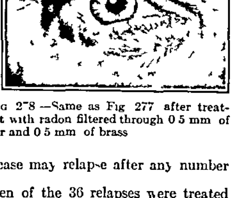

Fig. 278.—Same as Fig. 277 after treatment with radon filtered through 0.5 mm. of silver and 0.5 mm. of brass.

treatment. Nevertheless an occasional case may relapse after any number of years.

Treatment of Recurrences.—Twenty seven of the 36 relapses were treated again with the roentgen rays and 23 recovered; in 1 case the result was un

known, while 3 failed to improve Two of the recurrences were cured with radium; 1 by surgical excision; 1 with the Sherwell operation (curettage and acid nitrate of mercury); 1 with excision and 4 cases were not treated. It will be noted that 12 cases relapsed a second time within a year after the second recovery. Three of these lesions again disappeared under further x-ray treatment, 1 under radium, 1 under radium and Sherwell operation, 2 responded to the Sherwell operation; 1 remained untreated, in 2, treated with x-rays, the result was unknown, 1 treated with x-rays resulted in a failure as did also one treated with radium. To recapitulate, 23 out of 27 primary relapses responded immediately to the roentgen rays, in 1 the result was unknown and 3 failed to get well One of the 12 secondary recurrences was untreated, in 2 treated with x-rays the result was unknown, 1 treated with x-rays resulted in failure as did also 1 treated with radium Seven responded to various types of treatment. From the foregoing it will be seen that a relapse should not cause unnecessary alarm.

TABLE 19 —CURES, FAILURES AND RELAPSES IN RELATION TO PREVIOUS TREATMENT

	No cases	No previous treatment	Excision	Cauterization	Curettage	X-rays or radium	Electrolysis	Caustics
Cures		56%	6%	0 7%	7%	12%	3%	15%
	286	160	16	2	21	34	10	43
Failures		33%	9%			39%		18%
	33	11	3			13		6
Relapses		23%	14%		8%	28%	8%	18%
	21	5	3		2	6	2	4

Effect of Previous Treatment. An attempt was made to ascertain if previous treatment altered the susceptibility of the lesion to intensive roentgenization. The result of this study is shown in Table 19 There were 421 clinically cured cases of which the previous treatment was known in only 286 Seven cases are omitted from the 40 failures because the previous treatment could not be ascertained and 15 cases are omitted from the 36 relapses for the same reason The most noteworthy feature here is that 39 per cent of the failures were in cases that had been treated previously with x-rays or radium, usually the former in small doses over long periods of time. The percentages are obtained from the total number of cases as shown in the first column with the exception of the relapses Here the "cured and not followed" cases were first deducted

Results in Relation to Number of Treatments —Table 20 shows the results in relation to the number of treatments given. Only the cases with known end results are recorded—461 cases It will be seen that 196 cases, 42 per cent of the total of 461, were cured as a result of one treatment Or, considering only the cured cases (421), 46 per cent were cured in one treatment, 38 per cent in two treatments, 8 per cent in three treatments, etc It is interesting to note that 7 obstinate cases received as many as six intensive treatments with 3 cures, 4 failures and 1 relapse The percentage of cures is high as far as the second treatment. It would seem from this, as might be assumed, that if a lesion is not favorably influenced by two or three hyperintensive treatments, the chances of producing the desired result with the roentgen rays is lessened The percentages are obtained from the number of cases treated, with the exception of the relapses Here the "cured and not followed" cases are first deducted from the total number of cases

The study outlined in Table 21 does not give the true comparative value of filtered and unfiltered radiation because, as a rule, the lesions that received

filtered treatments were more deep-seated larger and more indurated than were the lesions treated without a filter The percentage of relapses is obtained after deducting the "cured and not followed" cases from the total number of cures The other percentages are taken from the total number of cure

TABLE 20 —RESULTS IN RELATION TO NUMBER OF TREATMENTS

Number of treatments.	Number of cases.	Cures.	Clinical cures not followed	Relapses	Failures.
1	?08	196 4?%	24 5%	6 3 %	12 3%
2	1?3	163 3?%	?3 ?%	15 10 %	10 2%
3	39	36 7%	8 2%	7 25%	3 0 6%
4	15	12 3%	7 2%	3 60%	3 0 6%
5	10	6 1%	1 2%	4 80%	4 0 8%
6	7	3 0 6%		1 33⅓%	4 0 8%
	2	1 0 2%			1 0 2%
8	4	2 0 4%			2 0 4%
9	?	1 0 ?%			1 0 2%
10	1	1 0 ?%			

TABLE 21 —FILTERED VERSUS UNFILTERED X-RAYS

	Number of cases	Cures	Cures not followed	Relapses	Failures
Unfiltered	409	388 94%	5? 13%	2? 6 %	21 6%
Filtered	5?	33 ?5%	11 2%	14 66⅔%	19 34%

Number of Treatments Required —Some idea of the difference in malignancy or obstinacy of the lesions may be obtained by a glance at Table 23 which shows the number of treatments necessary in individual cases both with filtered and unfiltered radiation

The key to Table 23 is as follows

In the first vertical column there were 200 out of a total of 409 unfiltered cases that received only one treatment Of these 200 cases 193 were cures and 7 *failed to improve* *Therefore 47 per cent of the 409 unfiltered cases were* 'cured' in one treatment The total 409 is obtained by adding the various unfiltered totals in the first horizontal column In the second vertical column we find that 8 out of 62 filtered cases received one treatment Three of these patients were cured in other words, 6 per cent of the total number of filtered cases were cured in one treatment The failure percentage is also taken from the total 52, but for the relapses the cured and not followed case is deducted

from the 3 cures and the percentage obtained from the remaining 2 cases that were "cured" and that remained under observation

Fig 279 Fig 280

Fig 279 —Recurrent basal-cell epithelioma confirmed by biopsy The lesion was originally treated with electrosurgery but recurred The patient was then given three treatments of filtered x-rays, each treatment consisting of 800 r The lesion involuted but recurred a year later

Fig 280 —Same as Fig 279 after treatment with very low voltage (50 kv) lightly filtered (2 mm Al) x-rays The patient was given 300 r every other day for a total of ten treatments The lesion disappeared and there has been no recurrence since August 10, 1938

Effects of Curettage —After eliminating the cases with unknown results, there was a total of 275 lesions that were curetted immediately preceding the application of the roentgen rays. Table 22 gives a comparison between the results obtained in cases that were and those that were not curetted

Table 22 —Comparison of Results in Curetted and Noncuretted Cases

	Number of cases	Cured	Cured, not followed	Relapses	Failures
Curetted	275	92% 254	8% 21	9% 17	8% 21
Not curetted	186	89% 167	25% 42	15% 19	11% 19

The percentage of relapses, as in the other tables, to be of true statistical value, has been obtained after subtracting the "cured" cases that failed to remain under observation from the total of "cured" cases The other percentages are obtained from the totals in the first vertical column It will be seen that there is not much difference in percentage between the "cures" that followed curettage and those that were not curetted Also the number of "cures" as a result of one treatment is about the same in both instances (Table 24) As a matter of fact, however, there was quite a marked differ-

TABLE 23.—FILTERED AND UNFILTERED CASES IN RELATION TO NUMBER OF TREATMENTS

	1 treatment		2 treatments		3 treatments		4 treatments		5 treatments		6 treatments		7 treatments		8 treatments		9 treatments		10 treatments	
	Unfilt	Filt	Unfilt	Filt	Unfilt	Filt	Unfilt	Filt	Unfilt	Filt	Unfilt	Filt	Unfilt	Filt	Unfilt	Filt	Unfilt	Filt	Unfilt	Filt
No cases	00	8	154	19	31	8	13		4	6	4	3				4	2		1	
	47%	6%	30%	26%	7	11%	[illegible]	3%	0.5%	7%	0.5%	[illegible]				2%	0.2%		0.2%	
Cures	193	3	149	14	30	6	10	2	2	4	[illegible]	1		1		2	1		1	
	3%	5%	7%	63%	16%	100%	50%	100%		100%	50%									
Relapses	5	1	10	5	4	3	2	1		4	1									
	[illegible]	9%	1%	9%	0.2%	3%	7%		0 [illegible]	3%	0.5%	[illegible]		[illegible]		[illegible]	0 [illegible]			
Failures	7	5	5	5	1	2	3			[illegible]	1	[illegible]		1		2	1			
Cures not	11%	33⅓%	11%	42%	[illegible]	50%	60%	50%	50%											
followed	23	1	17	6	5	3	6	1	1											

TABLE 24.—CURETTED AND NONCURETTED CASES IN RELATION TO NUMBER OF TREATMENTS

	1 treatment		2 treatments		3 treatments		4 treatments		5 treatments		6 treatments		7 treatments		8 treatments		9 treatments		10 treatments	
	Curetted	Not curetted	Curetted	Not curetted	Curetted	Not curetted	Curetted	Not curetted	Curetted	Not curetted	Curetted	Not curetted	Curetted	Not curetted	Curetted	Not curetted	Curetted	Not curetted	Curetted	Not curetted
No cases	12[illegible]	83	101	72	30	9	4	11	5	5	4	3	1	1	4		1	1		1
	43%	[illegible]	31%	36%	10%	3%	1%	4%	1%	1%	0.7%	0.5%	0.3%		0.7%			0 [illegible]		0.5%
Cures	117	79	90	67	29	7	3	9	4	[illegible]	[illegible]	1	1		2			1		1
	0 9%	7%	10%	10%	12%	100%		100%	66⅔%	100%	50%									
Relapses	1	5	10	5	3	4		3		[illegible]	1									
	3%	[illegible]	1%	3%	0.3%	1%	0.3%	1%	0.3%	1	0.7%	1%		0.5%	0.7%		0.3%			
Failures	8	4	5	[illegible]	1	2	1	2	1	3	2	[illegible]		1	[illegible]		1			
Cures not	10%	15%	3%	31%	13%	50%	66⅔%		66⅔%	[illegible]										
followed	12	12	3	20	4	3	2	6												

ence in this respect as in most of the curetted cases the second treatment was simply given as a precaution against recurrence. Whether or not this second treatment was necessary is not known Table 24 gives at a glance the number of treatments required in the curetted and noncuretted cases It will be noted that the percentage of recurrences is less in the curetted cases

The percentages in Table 24 were obtained exactly as in Table 23 Here we see that 43 per cent of the total number of curetted cases was cured in one treatment and 42 per cent of the cases that were not curetted was also cured in one treatment

Effect of Location.—On account of the frequent statements to the effect that epitheliomas in certain locations are particularly recalcitrant it was thought advisable to classify the results according to locations. Table 25 provides these statistics

FIG 281

FIG 282

FIG 281 —Rodent ulcer

FIG 282 —Same as Fig 281, after one ultraintensive x-ray treatment This patient had previously received 100 or more fractional treatments Total dose was probably 8000 r Subsequently there was a recurrence which failed to yield either to x-rays or radium Ultimate cure was obtained with electrosurgery

According to Table 25 the most stubborn lesions are those located on the eyebrows Here we find 75 per cent cures, and 25 per cent failures, as against 100 per cent cures for lesions on the trunk, lip and external canthus The following is the key to Table 25

Refer to the nose cases (first transverse column) The total number of cases is 169 This includes the cures, 150, and the failures, 19 The unknown cases (patients not reporting after the cessation of treatment) are not included The percentages of cures and failures are taken from the total 169 The percentage of relapses is obtained from the cures after deducting the "cured and not followed" cases

Cases Grouped According to Clinical Type.—A compilation of statistics based on the clinical characteristics of the lesions offers material of prognostic value In Table 26 an attempt has been made to divide the cases into groups possessing distinct clinical characteristics The nodular lesions were those which consisted of a single nodule, or a group of coalesced nodules These lesions, while at times quite thick, were for the most part superficial They ranged in size from a split-pea to a dime and, occasionally, a quarter They were not ulcerated nor crusted The ulcero-nodular lesions were nodular lesions

TABLE 25.—RESULTS ARRANGED ACCORDING TO LOCATION

	Number of cases.	Cures	Cured not followed	Relapses.	Failures
Nose	169	88% 150	12 % 18	11 % 15	11% 19
Inner canthus	19	99% 18	11 % 2	12 % 2	5% 1
External canthus	9	100% 9	100 % 9		
Forehead	61	90% 55	60 % 33	27 % 6	9% 6
Eyebrow	4	75% 3	100 % 3		25% 1
Cheek	90	93% 84	50 % 42	14 % 6	6% 6
Lip	16	100% 16	43 % 7	33⅓% 3	
Chin	13	92% 12	100 % 12		7% 1
Ear	14	78% 11	63 % 7	25 % 1	21% 3
Behind ear	10	100% 10	70 % 7		
Eyelid	11	90% 10	60 % 6		9% 1
Neck	12	91% 11	72 % 8	66⅔% 2	8% 1
Trunk	26	100% 26	19 % 5	4 % 1	
Hand	7	85% 6	66⅔% 4		14% 1

TABLE 26.—RESULTS ARRANGED ACCORDING TO CLINICAL TYPE

	Number of cases.	Cures	Cured not followed	Relapses	Failures.
Nodular	171	97% 166	1[illegible]% [illegible]	9% 13	2% 5
Superficial ulcer	65	100% 65	13% 9	10% 6	
Ulcero-nodular	111	88% 98	13% 13	8% 7	11% 13
Deep infiltrated ulcer	56	66% 37	21% 8	31% 3	33% 19
Infiltrated plaque	23	95% 2	9% 2		4% 1
Verrucous	11	91% 10			9% 1
Unclassified	24	95% 23	26% 6	5% 1	4% 1

which had undergone more or less ulceration. Many of these lesions were as large as a fifty-cent piece and some were the size of a silver dollar. The superficial ulcers were lesions ranging in size from a split-pea to a silver dollar, free of nodules and induration At times these consisted of hardly more than a superficial erosion covered with a crust The deep, indurated ulcers in size ranged from a quarter to an adult hand. The induration was dense and the ulceration extended into the subcutaneous tissue and in many instances involved the muscles and other important structures. The infiltrated plaques represent split-pea to quarter-sized areas of adherent hyperkeratosis with underlying infiltration The verrucous lesion is the infiltrated plaque just mentioned with a papillomatous or verrucous surface.

TABLE 27 —LESIONS OF VARIOUS CLINICAL TYPES ARRANGED ACCORDING TO NUMBER OF TREATMENTS

Clinical appearance	No cases	1	2	3	4	5	6	7	8	9	10
		48 %	34%	8%	4%	1%	0 5%				
Nodular	167	81	59	15	8	3	1				
Superficial		60 %	33%	4%			1%				
ulcer	65	39	22	3			1				
Ulcero-		34 %	44%	9%	3%	4%	2%				
nodular	105	36	17	10	4	5	3				
Deep infil-											
trated		2 %	51%	20%	5%	2%					
ulcer	54	10	28	11	3	2					
Infiltrated		90 %	8%								
plaque	23	21	2								
		81 %	18%								
Verrucous	11	9	2								
Unclassi-		33⅓%	36%				5%	5%	11%	5%	2 %
fied	36	12	13				2	2	4	2	1

The key to Table 26 is as follows

In the first horizontal column is shown the result obtained in the nodular type of epithelioma of which there were 171 cases which were kept under observation for at least a few months The percentage of cures and failures is obtained from this total. The percentage of relapses is obtained from the cures after deducting the "cured and not followed" cases

It will be seen that the highest percentage of cures and the smallest percentage of recurrences were obtained in the superficial ulcers Next in order come the ulcero-nodular and the infiltrated plaque

Table 27 shows the number of treatments administered to the various clinical types Only the "cured" cases and the failures are recorded It will be noted that 91 per cent of the infiltrated plaques responded to one treatment as against 81 per cent for the verrucous, 60 per cent for the superficial ulcers, and 48 per cent for the nodular lesions

Degrees of Reaction Observed.—Table 28 shows the effect of varying degrees of x-ray reaction on the epitheliomas Statistically, the best results were obtained without reaction The statistics, however, are misleading, because it is necessary to consider the clinical type, the number of treatments, etc

Effect of Age on Results.—Table 29 records the results in individuals of different ages. These statistics indicate that the best results are obtained in people between fifty and sixty years of age but the number of cases was too

small to be of value The next best showing was between the ages of seventy one and eighty five, although when the table is carefully studied it is seen that age makes very little difference The percentages were estimated in the same manner as those in Table 28

TABLE 28 —RESULTS IN RELATION TO DEGREE OF REACTION

Reaction	Number of cases	Cured	Cured not followed	Relapses	Failures
No reaction	29	99% 27	3% 1		6% 2
1st degree	49	87% 43	4% 2	9% 4	13% 6
2d degree	19	87% 17		32% 6	10% 2

TABLE 29 —RESULTS IN RELATION TO AGE OF PATIENT

Age.	Number of cases	Cures	Cures not followed	Relapses	Failures
20–30	12	91% 11	27% 3	[illegible]% 2	8% 1
31–40	48	89% 43	37% 16	14% 4	10% 5
41–50	106	85% 91	18% 17	16% 12	14% 15
51–60	121	97% 118	10% 12	10% 11	9% 3
61–70	77	89% 69	20% 14	3% 2	10% 8
71–85	40	95% 38	2% 1	5% 2	5% [illegible]
Unknown	57	89% 51		5% 3	10% 6

Effects of Sex on Results —The last table (Table 30) shows the results in relation to sex The best results were obtained in females The percentages here were obtained in the same manner as those of the preceding table

TABLE 30 —RESULTS IN RELATION TO SEX

Sex	Number of cases	Cures	Cures not followed	Relapses	Failures
Male	232	90% 210	15% 33	10% 18	9% 22
Female	229	92% 211	14% 30	9% 18	7% 18

Technic —Lesions may be treated by external or by interstitial irradiation Either radium or *x*-rays may be used for external irradiation For simplicity in visualizing the various forms of radiant energy

useful in the treatment of cutaneous malignancies, the following table may be referred to:

A. External irradiation
  1 Radium
    (*a*) Plaque.
    (*b*) Radium or radon pack.
    (*c*) Radium bomb
    (*d*) Radon or radium tubes or needles.
  2 X-rays.
    (*a*) Single large massive dose filtered or unfiltered.
    (*b*) Pfahler's saturation technic.
    (*c*) Coutard's method of protracted doses.
    (*d*) Chaoul's method of low-voltage contact irradiation.

B. Interstitial radiation
  1 Radium element needles
  2 Radon seeds.

C Interstitial combined with external radiation

D. Radiation combined with surgical methods.

The best method or combination of methods must be selected for each lesion treated The method selected depends upon the size, location and type of lesion, whether previously treated and the method used, the age, physical condition and sex of the patient

The ordinary small (less than 1 cm) superficial basal-cell epithelioma so often seen on the cheeks or forehead can be easily eradicated by irradiation with x-rays As a rule, a single dose of 900 r without filtration administered at one sitting is sufficient for a permanent cure The more usual technic is to apply 300 r without filtration every third day until a total of at least 2100 r are administered The lesion, of course, is shielded within 0 5 cm of the palpable or visible margin Preliminary curettage or biopsy is not necessary. The factors usually employed are 100 kv , 2 or 3 ma , skin-focal distance of 8 inches (20 cm.) and no filter

Larger lesions are treated with a minimum of 2100 r Every second or third day 300 r are administered. The infiltrating lesions are treated with filtered radiation and higher voltage. The total number of roentgens may reach 4000 to 6000 In rare instances as many as 7500 r may be given The factors usually employed are 140 kv , 5 to 10 ma , skin-focal distance of 10 inches (25 cm) and a filter of 3 mm. Al Each day 200 to 300 r are administered. Three hundred r daily for twenty-four days with this quality radiation will provoke a very intense radiation reaction This dose is seldom employed for the treatment of cutaneous malignancies

The 4-gm radium bomb is available to so few and its uses are so limited that it will not be discussed here.

Radium.—It is the opinion of the writers that x-rays and radium have the same value in the treatment of basal-cell epithelioma In individual cases, however, there is a difference Some think that the

results obtained with radium are superior to those obtained with x-rays. We do not believe that this superiority has been definitely established. Occasionally a tumor will undergo involution under the influence of radium after x-rays have failed to be of benefit. We have never been able to cure a basal cell epithelioma with x-rays after failing with radium. Also we have not been able to accomplish with gamma rays what could not be done with filtered medium voltage x-rays. Radium is more convenient and for this reason, more efficacious when the disease is located in inaccessible locations, such as the edge of the eyelid, the external auditory canal, or when the nasal or buccal mucosa is involved. Also, in many instances, it is easier to cross fire, or to obtain a plane radiating surface for convex and irregular surfaces with radium than with x-rays. At times both agents may be used to advantage as, for instance, a tumor on the nose might be treated by applying x-rays externally while a radium tubular applicator is placed in the nose.

If the lesion is thoroughly curetted under procaine anesthesia it will often suffice to apply an unscreened glazed one half-strength plaque to the wound for about twenty minutes. The surface of the applicator should, of course, be protected with a layer of dental rubber or oiled silk. Those having a 10 mgm. half-strength plaque with monel facing may apply it in contact with the lesion without additional filtration except for the thin layer of rubber tissue for a period of one to one and one-half hours.

Lesions that are more than a few millimeters in thickness are usually treated with gamma rays. A half-strength flat applicator, screened with 2 mm. brass and 1 mm. aluminum may be held in contact with the lesion for at least twenty-four hours, and, in some instances, even longer. It is customary to give daily exposures of between two and four hours each.

Because of location, size, depth and shape of the lesion it is often preferable to employ radon. One 50-millicurie tube (or 50-mg. element tube, or a group of needles containing this amount of radium or radon) with a wall thickness of 0.5 mm. Pt. is used for each square centimeter of surface. By means of soft wood or modeling compound the applicator is placed at a distance of 1 cm. The exposure is eight hours or longer. Tubes containing 100 mc. radon and filtered through 1 mm. Pt and enclosed in a rubber sac held in contact for two hours will cause involution of many basal-cell epitheliomas.

In some instances better results can be obtained by implanting gold seeds into the growth, or by inserting radium needles in and around the periphery of the lesion.

Regaud, Cole and Driver, Shelmire and Fox, Martin, Zeisler and others have reported excellent results in the treatment of cutaneous malignancies with radium. Each of the many methods of radium or radon application which have been used has its own peculiar advantage in certain types of growths. It is therefore impossible in this work to

discuss in detail all the methods. At the Memorial Hospital, New York City, Martin employs most commonly radon plaques at 1 cm. distance and filtered with an equivalent of 3 mm. brass. The usual dose for small lesions is between 1000 and 1500 mc.-hr. Next in order are: unfiltered radon bulbs, gold seeds, *x*-rays, surface contact applicators and radon tray.

Cole and Driver, and Shelmire and Fox employ interstitial radium element needles. The needles remain in the tissue from one hundred to one hundred and sixty-eight hours and are placed in such a way as to surround the tumor mass The needles are placed 1 cm. apart.

It must be borne in mind that when using this method of irradiation, important underlying and surrounding structures should be sufficiently protected to avoid damage to them. Periosteum, cartilage and the eyes must not be overexposed.

Small (0.5 to 1 cm.) lesions at the edge of the eyelids may be treated by the implantation of 1 or 2 gold seeds containing 1 mc of radon. Larger lesions are treated with more seeds each containing 0.5 to 0.75 mc. of radon. These seeds are permanently embedded into and/or under the lesion A good working rule to follow in the treatment of basal-cell epitheliomas with radon implants is to use for lesions less than 1 cubic centimeter, 1 radon seed of 1 mc.; for lesions up to 8 cubic centimeters, 0.75 mc. per cubic centimeter, and for lesions greater than 30 cubic centimeters, 0.5 mc. per cubic centimeter. This rule is very elastic and should serve only as a guide to the beginner until he acquires sufficient experience

Irradiation combined with destructive measures such as curettage or electrosurgery often yield better results than when either is used alone

Method of Election.—The object of any treatment is to destroy every malignant cell. If this can be accomplished a cure is the result. So far as statistics are concerned this object in unselected cases is most nearly attained by irradiation or by surgery.

Both methods possess advantages and disadvantages. The principal disadvantage of excision is the difficulty of removing all pathologic tissue. This is especially true in large, deep-seated, adherent lesions or lesions that are situated in inaccessible locations such, for instance, as the inner canthus. Even when dealing with a small epithelioma limited entirely to the skin and situated in a favorable location, the surgeon, in an endeavor to obtain a good cosmetic result and for other reasons, is likely to cut too close to the macroscopic lesion thereby leaving malignant cells *in situ*. In a number of supposedly successful excisions we have obtained the excised tissue *in toto*, cut it serially and found that the proliferated epithelial cells extended to the edge of the incision It is a question if such an examination should not be made after every excision and, if the indications warrant, *x*-rays or radium be employed to prevent a recurrence.

Other objections to excision are the shock to old and feeble persons,

FIG 283 — A superficial basal cell epithelioma near the breast and a deep rodent ulcer in the axilla

FIG 284 —Same as Fig 283 after one strong unfiltered x ray treatment applied to each lesion No recurrence in seven years The number of roentgens used was probably 600

loss of time, pain and deformity Scalpel excision, when properly performed, has the advantage of microscopic diagnosis.

When treating epithelioma, even a small basal-cell growth, the principal object is to destroy the disease completely. While the cosmetic result is worthy of serious consideration, it is of secondary importance. It is the duty of the physician to select a method of treatment that in his opinion will most likely eradicate the disease If there is a method that will accomplish this purpose and at the same time give a superior cosmetic result, such treatment will constitute the method of election

FIG 285

FIG 286

FIG 285 —Basal-cell epithelioma of the right side of the nose

FIG 286 —Same as FIG 285, after treatment with *x*-rays The patient received low voltage (100 kv) unfiltered *x*-rays A dose of 300 r was given every other day for a total of 10 treatments

Small lesions can be destroyed with *x*-rays or radium and the cosmetic result may be so perfect that it is impossible to detect the former site of the disease On the other hand there is always the possibility of such sequelæ as atrophy and telangiectasia In this connection, in the senior author's series of 644 patients, there were only 6 cases of telangiectasia and these occurred in resistant cases that required considerable treatment. Telangiectasis subsequent to a first- or second-degree radiodermatitis is not an uncommon phenomenon and it is curious why it does not occur more often in epithelioma cases Possibly this "immunity" is due to the fact that most of the patients are beyond forty years of age

Excision usually leaves more or less scarring Ulcerated and deeply infiltrated lesions that involve the true skin or the subcutaneous tissue will leave a scar no matter how treated, but the deformity is less subsequent to irradiation than to any other form of treatment. Without entering into further argument, suffice it to state that insofar

is cosmetic results are concerned x rays and radium offer distinct advantages over other methods

It is doubtful if there can be a method of election for unselected cases of basal cell epithelioma The experienced physician will select the method or combination of methods that promises the best result in the individual case However, assuming that excision, powerful caustics, curettage, electrosurgery or irradiation will, when adequately applied cure the average case of basal cell epithelioma, the authors favor the last method The reasons for the selection are as follows There is no pain nor inconvenience in the case of a healthy and active person and no shock, mental or physical, to aged or weak or nervous patients There is no interference with vocations The often injurious psychologic effect of surgery is avoided The cosmetic results are superior to those obtained by other methods It is therefore, a reasonable routine in most cases to try irradiation first

Prognosis Affected by Previous Treatment —It is well known that certain methods of treatment or almost any treatment inadequately applied may make a basal-cell epithelioma more stubborn Presumably this increased malignancy is caused by the lowering of vitality of the surrounding tissues The most stubborn lesions are those that have received repeated courses of x-ray treatment administered in small doses It is advisable therefore when selecting a method of procedure to consider the previous treatment and its result If there is a history of long-continued irradiation or if the skin in the neighborhood of the lesion (original or recurrence) shows x ray sequelæ it would seem advisable if possible to employ some method other than x rays or radium

Recalcitrant Lesions —If a lesion does not respond favorably to hyperintensive irradiation it is advisable to utilize some other method instead of proceeding with roentgenization indefinitely Some roentgenologists will not agree with this statement They are convinced that every basal cell epithelioma can be cured with the x rays or with radium if the dose is sufficiently intensive the treatment being pushed to the point of producing a third-degree radiodermatitis if necessary In confutation of this opinion the authors have studied tissue removed from x ray ulcers (on the site of a basal cell epithelioma) of long duration and found actively proliferating basal cells deep in the tissue or at the edge of the ulcer

When x rays or radium fail to cure a basal cell epithelioma, the failure is usually due to neglect, poor judgment, inadequate or improper treatment etc However it must be admitted that there are basal cell tumors even very small lesions that have never been treated that simply cannot be cured with these agents Fortunately such instances are uncommon Montgomery has shown that about 13 per cent of epitheliomas clinically diagnosed as basal cell epithelioma contain prickle cells These mixed or basal-squamous cell epitheliomas are more radioresistant than pure basal-cell epitheliomas

If irradiation is going to be successful there will be distinct improvement subsequent to the first hyperintensive treatment. If such improvement is not manifest, further irradiation may not affect the lesion. It occasionally happens that a lesion will show improvement after the first two or three treatments and then irradiation loses its efficacy. In such instances additional irradiation is not warranted.

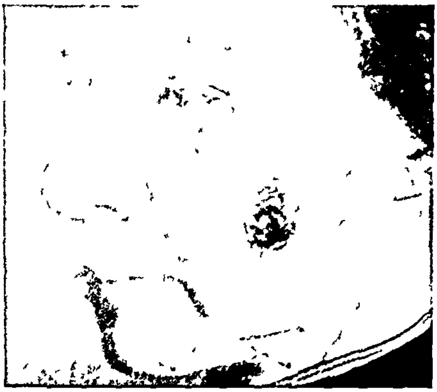

Fig 287

Fig. 288

Fig 287.—A deep-seated, indurated, basal-cell epithelioma Photograph was taken a few days after first treatment, note the areola of *x-ray erythema*

Fig 288 —Same as Fig 287, after two strong *x*-ray treatments Total dose was probably 1200 r The patient died (pneumonia) three years after the last treatment. There was no recurrence

Fig 289

Fig 290

Fig 289 —Large ulcero-nodular basal-cell epithelioma before treatment (Courtesy of Dr W A Pusey)

Fig 290 —Same as Fig 289 This patient was treated in 1903. No recurrence (Courtesy of Dr W A Pusey)

Intensive Versus Fractional Treatment.—It is generally agreed that repeated small doses (75 r) of unfiltered *x*-rays given at weekly or biweekly intervals are contraindicated in the treatment of epithelioma.

In former years it was the practice to administer small doses once or twice weekly until an erythema developed or until the lesion disappeared It was not unusual to give 50 or even 100 such treatments The percentage of clinical cures was small and the percentage of recurrences was large There is reason to believe that small doses induce radiosensitive malignant cells to become radioresistant and unless these small amounts are administered with sufficient frequency to provide rapid accumulation the result is likely to be undesirable Under fractional treatment the disease may disappear, but it is more likely to persist and even progress more rapidly and it may become more resistant to any form of treatment As a rule an epithelioma that has been treated with fractional irradiation will not respond favorably to an intensive treatment unless several months have elapsed *since the last fractional treatment was administered* Pusey has always been an advocate of fractional treatment and his results have been

Fig 291 Fig 292

Fig 291 —Basal cell epithelioma of the right cheek

Fig 292 —Same as Fig 291 after eight *x* ray treatments A dose of 300 r was given each time Kv was 50 the filtration was 2 mm of Al and the distance was 5 inches

excellent The explanation is simple Pusey's fractional treatment does not correspond with fractional treatment as outlined in Chapter XVI His dose is much larger and the intervals between treatments are shorter The desired effect is obtained within a month so that his routine is intensive rather than fractional As outlined in Chapter XXV intensive treatment may consist of a single erythema dose or smaller doses so spaced in time that the effect is the same Some roentgenologists employ intensive radiation at one sitting Martin gives 2500 to 3500 r to lesions measuring 6 to 20 cm This dose is administered at one sitting Dresser and Dumas employ a method which might be called modified Coutard technic They give 300 to 600 r daily or every other day for a total of 3000 to 8000 r These authors and others (Widmann, Coutard and Hollender) who have recently written on this subject, advocate the massive method of treatment Other roentgenologists now administer a fraction of this massive dose daily for a week or two In this way it is thought that

it may be possible to attack the cells at the time of division when they are much less resistant. In this way, also, a larger total dose can be given with less reaction. The method is especially popular with those who administer radium and particularly those who do deep therapy.

Preliminary Curettage.—Fordyce was the first to suggest preliminary curettage. Belot and others have found the idea an excellent one. The method has advantages and disadvantages. The procedure is surgical and is associated with many of the objections given when discussing surgical methods. While it is advantageous to precede irradiation by curettage, this step is by no means necessary in the majority of cases. With preliminary curettage one is more certain to obtain a cure with less radiation, especially is this true of nodular, or deep-seated, or indurated lesions. In well-advanced lesions, the percentage of clinical cures is greater with than without curettage. Basal-cell epitheliomas being nonmetastatic, curettage may be performed with safety.

Quality of Radiation.—There is a difference of opinion among roentgenologists as to the best wave length to use for the treatment of cutaneous epithelioma. Some writers advise a kilovoltage of 140 to 200 and heavy filtration for all cases, others prefer a kilovoltage of 60 to 100 with or without filtration. Schultz has obtained good results with a 2-inch spark gap in cases that failed to yield to a more penetrating radiation. At times a lesion that failed to resolve under the influence of unfiltered radiation will disappear when subjected to filtered radiation. The opposite also occasionally happens. The opinion expressed by Widmann in the discussion of the paper by Dresser and Dumas is that in superficial cancer quality makes no difference in results, the quantity of x-rays administered is the important fact. This opinion is shared by many dermatologists and roentgenologists. A perusal of the statistics of the therapeutic results obtained in the treatment of cutaneous malignancies by radiation of different wave lengths varying from grenz rays (10 kv.) to high-voltage x-rays and heavy filtration (200 kv. and 2 mm. Cu) confirms this opinion. We recently treated 2 parallel series of basal-cell epitheliomas. One series was treated with 50 kv. and 2 mm. Al filter and another series with 135 kv. and 3 mm. Al filter. The results were the same in both series. Unfortunately there is no statistical evidence pointing to the superiority of any given wave length used as a routine. Our impression is that it makes little difference what kilovoltage is used, within reasonable limits, as a routine. But it is inadvisable to establish a routine technic for the treatment of basal-cell epithelioma. If all visible or palpable evidence of disease is removed with a curette it is difficult to understand the advantage of applying filtered radiation to the open wound. Theoretically, "soft" radiation would be of possible advantage here. Small, very superficial lesions seem to respond equally well to filtered or unfiltered radiation. Filtration is

specifically indicated in large, thick lesions, especially when the entire derma and the subcutaneous tissue are involved

Eyelid Lesions —The main question here concerns suitable protection of the eye. While this organ tolerates larger amounts of radiation without injury, it should be protected as much as possible. If the lesion is situated on the lower lid, the lid can be pulled away from the eyeball and fastened in place by a strip of zinc plaster, one end of which is attached to the lid while the other end is fastened to the neck. When treating lesions on the upper eyelid it is customary to cocainize the eye and to insert under the lid eye shields composed of lead glass or brass. The grenz rays would appear advantageous for amenable eyelid lesions. Martin has shown that the cornea receives less radiation when eyelid lesions are treated by radon implants than when treated by external or surface irradiation

CAUSES OF FAILURE

1 **Failure to Destroy Lower Strata of Cells** —A lesion may appear to be clinically cured while the epithelial cells in the deeper part of the growth continue to proliferate. Or such cells may remain inactive for a few weeks or months and then begin to proliferate. Failure to apply a lethal dose to these cells may be due to the use of unfiltered radiation when filtration is indicated, or the individual or collective dose may be too small. In order to apply a lethal dose to deep seated cells it may be necessary to use filtered radiation, to use high voltage radiation, to cross fire, to apply as large doses as possible without seriously injuring normal tissue, or to use interstitial irradiation

2 **Resistant Cells** —Rarely one encounters an untreated basal-cell epithelioma *that fails to resolve under the influence of x-rays or radium*. Such resistance is common in cases that have been inadequately or improperly treated with these or with other therapeutic agents. In either instance it is inadvisable to continue the use of x rays or radium *beyond a fair trial*, although recent reports seem to indicate that if 10 to 20 skin erythema doses are employed by using the modified Coutard technic these resistant lesions will respond

It is probable that cells comprising a malignant neoplasm vary in susceptibility to irradiation and this variation is due to the life cycle of the cell. A cell during its rest stage is less susceptible than one that is undergoing division. It is conceivable, therefore, that at the moment of treatment there might be cells capable of resisting the usual therapeutic dose. This theoretical possibility suggests the advisability of one or two "prophylactic" treatments when a lesion is apparently cured with one application. The prophylactic doses may be intensive or subintensive, rather than hyperintensive

Theoretically there is a better way to insure against the escape of cells in the rest stage. Kingery has shown that 50 per cent of x ray effect is lost in three and a half days, therefore to keep the tissue in a

state of saturation for a period of several weeks it is necessary to administer one-half saturation dose every three and a half days. The details of Kingery's method are given in a previous chapter. In discussing the saturation technic of Pfahler, Padgett points out that the skin tissues recover 60 to 70 per cent during the first twenty-four hours and not 5 to 10 per cent as was previously thought.

As previously mentioned in this chapter, many of the stubborn examples of basal-cell epithelioma are of mixed type; that is, they contain cells that are derived from layers above the basal-cell layer of the epidermis. Naturally, such lesions are likely to be comparatively unyielding to irradiation.

3. **Inadequate Dosage.**—No one has estimated, experimentally, the amount of radiation required to destroy all the malignant cells in a basal-cell neoplasm. Wood and Prime and others have determined the lethal dose for prickle-cell epithelioma. Practical experience shows that the lethal dose for basal-cell epithelioma is considerably less than for prickle-cell epithelioma. A single erythema dose (300 r) properly administered will suffice for many tumors of the basal-cell type, whereas at least 900 r are necessary for a prickle-cell growth. Judgment, experience and skill in observation are required to determine adequate treatment in a given case. It is preferable to apply a little more radiation than is necessary rather than an amount that is inadequate, but this must not be carried to the point of undue injury to normal tissue It is not justifiable to effect a third-degree radiodermatitis nor to cause an injurious degree of atrophy or sclerosis. At least 2000 r should be administered to a basal-cell epithelioma. It is preferable to use 3000 to 4000 r and the entire dose should be given in a period of two to four weeks

4 **Failure to Destroy Peripheral Cells.**—Many recurrences begin at the edge or just beyond the periphery of the former lesion. This may be due to too close shielding Histologic studies and practical experience demonstrate that malignant cells may extend for several millimeters or even a centimeter beyond the visible or palpable edge of the lesion It is essential, therefore, that at least 0 5 cm., preferably 1 cm, of normal skin around the lesion be included in the field of radiation.

Convex lesions, very large lesions, and lesions situated in inaccessible locations may interfere with the application of the lethal dose. Information relative to treatment under such conditions will be found in the chapter on General Therapeutic Considerations.

5 **Inadequate Observation.**—After a clinical cure has been established the site of the former lesion should be inspected every six months for five years Failure to keep patients under observation has been the cause of many obstinate and destructive recurrences The observer should be able to detect the earliest evidence of recurrence in, under, or beyond the scar.

Statistics Found in the Literature —A detailed statistical review of the results obtained in the treatment of basal-cell epithelioma is unnecessary The subject has been thoroughly covered by Janet Lane-Claypon in her statistical study of the world s literature up to 1930 While there is a voluminous literature dealing with the x-ray treatment of basal-cell epithelioma there are comparatively few articles that give carefully compiled statistics

The following table summarizes the results obtained by various workers utilizing different methods of treating basal cell epitheliomas Those who desire all the details published in connection with these statistical reports are referred to the original articles (bibliography at the end of this chapter)

TABLE 31 —STATISTICAL THERAPEUTIC TABLE BASAL-CELL EPITHELIOMA

Author	Year	Method	No cases	Per cent cures
Sequeira	1901	X rays	236	66 0
Williams C M	1906	X rays	16	68 5
Bisserié	1906	X rays	186	90 3
Williams E G	1907	X rays	53	98 0
Pusey	1907	X rays	111	76 0
Stern	1907	X rays	85	53 0
Hahn	1908	X rays	509	90 9
Sherwell	1910	Surgery and acid nitrate of mercury		90 0
Williams and Ellsworth	1913	Radium	181	85 4
Hazen	1919	Scalpel excision	64	93 0
Simpson F	1922	Radium	1000	About 100
Morrow and Taussig	1923	Radium	322	97 0
Quigley	1923	Radium	593[1]	84 4
Hazen and Whitmore	1925	X rays	244	88 8
Dolloway	1926	X rays	153	100 0
MacKee	1927	X rays	644	90 0
Montgomery	1928	Scalpel excision	18[2]	100 0
Archambault and Maisin	1930	Curettage and x rays	21	Results about the same by the two methods
Archambault and Maisin	1930	Surgical diathermy	32	
Falchi	1930	Surgical diathermy	21	61 9
Halberstaedter and Simons	1931	Interstitial radium	302	93 11
Belot		Curettage and x rays	6000[3]	85 0
Zeisler	1933	Curettage x rays and surgical diathermy	359	94 0
Shelmire and Fox	1936	Radium needles		95 0
Dresser and Dumas	1936	X rays		95 0

[1] Includes both basal and squamous cell epithelioma
[2] Five mixed type
[3] 85 per cent basal 10 per cent squamous 5 per cent mixed

Comment —It will be seen that the lowest percentage of clinical cures in any of the statistics is 53 per cent (Stern), while they run as high as 98 per cent (E G Williams) and 100 per cent (Dolloway and Montgomery) The lowest percentage of relapses was 1 per cent (Dolloway) the highest was 27 (Sequeira) It is of little practical

value to compare these statistics for some of them are incomplete, they treat the various items differently, some of them include both the prickle- and basal-cell types, while others do not, and the technics of the various authors differ For the same reason it is impractical

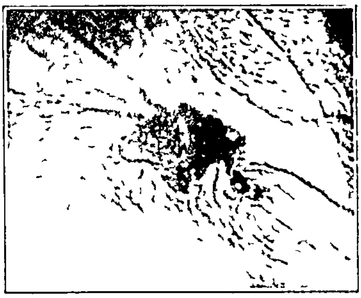

FIG 293 —Rodent ulcer.

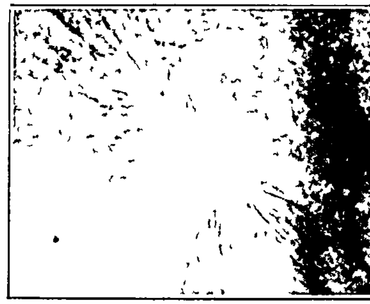

FIG 294 —Same as FIG 293, after two strong x-ray treatments Total dose was probably 1200 r No recurrence in eight years

FIG 295 — Rodent ulcer with indurated margin which had failed to heal under the influence of long-continued fractional roentgenization

FIG 296 —Same as FIG 295, after four hyperintensive, filtered x-ray treatments Total dose was probably 2400 r A subsequent recurrence failed to be influenced by x-rays or radium

to endeavor to obtain a mean average of temporary and permanent cures Most roentgenologists agree that it is possible to obtain as high as 98 per cent of clinical cures and from 94 to 96 per cent of permanent cures in selected cases of basal-cell epithelioma and from 80 to 90 per cent of permanent cures in unselected cases

In the senior author's statistics of unselected cases there was a percentage of clinical cures amounting to 90 with 15 per cent relapses. Most of the recurrences, however, responded to further treatment so that the original percentage of 90 is not materially reduced. It will be recalled that the cases that were observed for five years showed a percentage of permanent cures of 94, four-year cases 80 per cent, three-year cases, 82 per cent, two-year cases, 85 per cent. These percentages can be increased by omitting the recurrences that again healed under the influence of the x-rays.

Comparison of Methods of Treatment.—Now let us see how these statistics *compare with* those associated with other methods of treatment. Hazen reports a series of 178 basal cell epitheliomas which were *treated by surgical excision*. Eighty six per cent were permanently cured. Lane Claypon collected the following interesting data in the literature. Of the skin cancers (including both squamous and basal-cell epitheliomas) that were treated by operation only 40 to 50 per cent were permanently cured, whereas of those that were treated by irradiation, 80 to 90 per cent were permanently cured.

It will be seen that there is a real difference according to statistics, between the results obtained by surgical excision and by x-ray treatment. Our experience is the same as that of Hazen, namely, that there is very little difference between the results obtained by surgery and by irradiation. However, when the combination method is used, the percentage of cures is higher than when either one or the other method is employed. Sherwell obtained 90 per cent permanent cures in unselected cases with the vigorous use of acid nitrate of mercury after thorough curettage but this estimation is not based on carefully compiled statistics. The literature does not appear to contain statistics based on the use of the various caustics such as arsenic, solid carbon dioxide, *zinc chloride, actual cautery, electrosurgery, etc.* It has been claimed by A. Robinson and others that arsenical paste if properly employed gives as high a percentage of permanent cures as does any other method. The reader should not get the notion that we advise the use of caustics for the treatment of cutaneous malignancies.

BASAL-SQUAMOUS-CELL EPITHELIOMA

The basal squamous-cell epithelioma clinically resembles the basal-cell epithelioma but it is more resistant to therapy generally used for basal-cell epitheliomas. Hamilton Montgomery found that 12.6 per cent of a series of 119 cases of what appeared clinically to be basal-cell epitheliomas were found upon histologic study to be basal-squamous-cell epitheliomas. Curiously enough, this percentage of cases has proved stubborn to irradiation in doses usually sufficient to cure basal-cell epithelioma.

Treatment.—Excision or electrosurgical destruction combined with irradiation give the best results. If radium alone or x-rays alone are

used, the method to be used is that described in the next section under primary prickle-cell Epithelioma of the Skin.

PRIMARY PRICKLE-CELL (SQUAMOUS-CELL) EPITHELIOMA.

Cutaneous epithelioma of the squamous- or prickle-cell type may develop in the skin or in the mucosa We agree with Pusey, Boggs, Quick, and others who aver that most of these growths can be eradicated with x-rays or radium if the lesion is recognized sufficiently early and the treatment is immediately and properly applied. But we are not in accord with men who advise irradiation as the method of election in all cases of well-developed prickle-cell epithelioma even when there are no palpable glands.

FIG 297 —Keratosis involving the entire lower lip No perceptible underlying infiltration. Probably precancerous

FIG. 298 —Same as Fig 297, after two hyperintensive x-ray treatments. Total dose was probably 1200 r. The horny layer was first removed There was a little leukoplakia which also disappeared. No recurrence in seven years

Prickle-cell epithelioma is an exceedingly dangerous disease. Success lies in early diagnosis and the immediate institution of adequate treatment. Delay in diagnosis, or delay in instituting treatment, or inadequate treatment, is hazardous because metastasis may occur at any time. The absence of palpable glands does not mean absence of metastasis Very frequently local growths are permanently cured only to have the disease appear in the neighboring lymphatics a few months or a year or two later. This happens after surgery and after irradiation in cases that do not exhibit evidence of metastasis at the time of treatment It is probable, in such instances, and even in very early cases, that metastasis occurred prior to the treatment

FIG 299 —An ulcerated x ray keratosis occurring on the hand of a pioneer x ray technician probably a beginning prickle cell epithelioma

FIG 300 —Same as Fig 299 after two radium treatments (beta rays) No recurrence in eight years

FIG 301 —Prickle cell epithelioma

FIG 302 —The same as Fig 301 after two hyperintensive doses of filtered x rays Total dose was probably 1200 r No recurrence for five years

Because of the possibility of malignant cells being present in the neighboring lymphatics it is customary to irradiate the lymphatics that drain the site of the lesion While there is no convincing statistical evidence that such treatment is of value, the method is indicated theoretically Furthermore it is the opinion and impression of surgeons, radiologists and dermatologists that such treatment is of value. As there is some clinical evidence for this opinion, every patient with

Fig 303 —A section of tissue obtained by a biopsy from patient shown in Fig 301 Section shows a prickle-cell epithelioma

prickle-cell epithelioma, whether the primary growth is irradiated or excised, should receive the possible benefit to be derived from such treatment Incidentally, many surgeons after excising a lesion not only advise irradiation of the neighboring lymphatics but also the site of the former lesion

Transitional lesions, that is, a lesion in the transitional stage between a preepitheliomatous, growth and a true epithelioma and, also, very small prickle-cell epitheliomas of the skin or mucosa, can be destroyed

with x-rays or radium with a reasonable degree of certainty. After the lesion has become indurated, ulcerated, and has invaded the deeper derma and perhaps the subcutaneous tissue, the result of irradiation is uncertain. We recall with pardonable pride and pleasure our successful cases, and endeavor to forget the poor unfortunates who failed to respond favorably to the treatment. Success in our hands has been limited to a small percentage of unselected cases.

It is a well-known fact that the degree of malignancy is not always the same in tumors of the same morphologic type, also that the tumors behave differently when irradiated. We have failed to cure small but rapidly growing tumors having a duration of from three weeks to three months; failures have occurred also in less malignant tumors. On the other hand inoperable and apparently hopeless cases have been clinically cured and have remained well for from two to seven years.

Broders' Classification.—The differences in malignancy of the same clinical type of carcinoma in different locations is dependent upon the *amount of differentiation of the cells making up the tumor mass*. There are four grades of malignancies according to the classification of Broders, Grade 1 carcinoma being least malignant and Grade 4 most malignant.

Grade 1 carcinoma. The proportion of differentiated cells ranges from almost 100 down to 75 per cent, that of the undifferentiated cells range from practically 0 up to 25 per cent.

Grade 2 carcinoma. The proportion of differentiated cells ranges from 75 down to 50 per cent; that of undifferentiated cells from 25 up to 50 per cent.

Grade 3 carcinoma. The proportion of differentiated cells ranges from 50 down to 25 per cent; that of undifferentiated cells from 50 up to 75 per cent.

Grade 4 carcinoma. The proportion of differentiated cells ranges from 25 per cent to practically 0; that of undifferentiated cells from 75 up to 100 per cent.

Radiosensitivity of Tumors.—Radiosensitivity has been defined by Stewart as that combination of circumstances resident in the tumor or the host which permits marked or total local tumor regression under doses of radiation sufficiently small to preserve the integrity of the tissues of the host. There are different degrees of radiosensitivity. Ewing classifies them in the following decreasing order of radiosensitivity:

1. Lymphoma
2. Embryonal tumors
3. Cellular anaplastic tumors
4. Basal cell carcinoma
5. Adenoma and adenocarcinoma
6. Squamous cell carcinoma and fibrocarcinoma
7. Fibroblastic sarcoma, osteosarcoma and neurosarcoma

It is readily seen that tumors composed of rapidly growing cells are radiosensitive, whereas the sarcomas and the melanomas are radioresistant. It is also obvious that radiosensitivity is not dependent entirely upon the histologic structure of the tumor or upon tumor grading based upon the percentage of dedifferentiated cells Local conditions, such as vascularity, fibrosis, presence of infection, general health of the patient, previous treatment, metastases, etc, may influence the response of a tumor to irradiation.

Desjardins made an important contribution to the subject of radiosensitivity He asserts that sensitiveness seems to be related to the natural cycle of the cell. The lymphocytes are the most sensitive and have the shortest metabolic life cycle, while the nerve cells with the longest life cycle are the most resistant to irradiation. Attempts at increasing sensitiveness of tumors to irradiation by artificial means is still in the experimental stage. Various metals have been injected with the idea that secondary radiation would enhance the effect of the dose delivered Finally, in order truly to evaluate radiosensitivity, accurate means of reporting dosage must be universally adopted The establishment of the unit of quantity, the international roentgen, should create more uniformity in radiation dosage.

For further details dealing with radiosensitivity, the reader is referred to the many original articles written on this subject which is gaining increasing importance.

Technic.—The methods of treating squamous-cell carcinoma are many and differ according to the size and the location of the tumor, the previous treatment administered, the physical condition and the age of the patient, the presence or absence of metastasis, etc Rather than to generalize, it was thought best to describe in detail exact technic for squamous-cell carcinoma in different locations. This technic will apply to the majority of cases encountered For very far-advanced cases or extensive cases, it may be necessary to modify the method radically.

Squamous-Cell Carcinoma of the Skin—If secondary infection is present, wet dressings should be used before instituting active therapy Infection appears to influence the radiosensitivity of epitheliomas An early lesion measuring less than 1 cm. in diameter may be treated with one massive dose of *x*-rays provided that it has not been previously treated. The following factors may be used. 100 kv, 3 ma, skin-focal distance of 8 inches (20 cm) and no filter. Shield to within 1 cm of the palpable margin and deliver at one sitting 1800 to 2100 r A lesion over 1 cm. in diameter may be treated with a larger number of roentgens and with higher voltage, utilizing a modified protracted method of irradiation The following factors may be employed 140 kv, 5 ma, 3 mm. Al filter, skin-focal distance of 10 inches (25 cms.) Shield as above and give 200 r each day until a total dose of 4000 to 6000 r has been administered. The total amount of radiation depends to a certain degree upon the production of what Regaud termed radio-

epidermitis Larger lesions which had been previously treated or which had recurred must be treated with higher voltage (200 kv), greater filtration (2 mm Cu), larger total dose (8000 to 12,000 r), a low intensity time factor and the daily treatments protracted over a period of about two months

Chaoul s method has not been sufficiently used to predict results We have had no personal experience with this technic Reports thus far published are encouraging

Radium may be used in various ways Good results may be obtained by surface application in contact or at a distance We prefer to use gold radon implants If the lesion is over 1 cm in thickness, 1 mc of radon is used for each square centimeter of tumor The radon seeds are placed in proper position by instruments especially made for the purpose The seeds are placed in, around, and under the lesion A centimeter of apparently normal tissue is included in the treated area If the lesion is so small that only 1 or 2 seeds are required, each seed may contain 2 mc of radon Sometimes surface application of radium is combined with interstitial radiation

Radium needles of the type described in the section on Basal cell Epithelioma are very popular with some dermatologists The total dose depends upon the size of the lesion For each square centimeter of tissue 1 mg of radium is used and is kept *in situ* for five or six days *Most lesions require a minimum of 500 mg -hr*

Lesions involving cartilage are best treated by surgical excision, plastic operation or by electrosurgery Radiation may be used as supplementary treatment

Carcinoma of the Lip —Carcinoma of the lip becomes metastatic late and it is therefore possible to cure by irradiation as Kelly avers about 90 per cent of early cases Carcinoma of the lip is the least malignant of all cancers affecting the oral mucous membranes Certainly 50 per cent of unselected cases should be cured by a combination of irradiation and surgery The statistics collected speak equally favorably for the various methods used in the treatment of carcinoma of the lip The important thing is to employ the method with sufficient vigor to destroy completely the local lesion If metastatic nodes are present, then the prognosis becomes indeed grave

Early superficial lesions may be treated with unfiltered *x* rays, employing 100 kv , 3 ma , and a skin focal distance of 8 inches (20 cms) The entire lesion is exposed as well as a portion of the surrounding tissue One skin erythema dose (300 r) is given every second day until a total dose of 2400 r is administered For larger and infiltrating lesions without metastases, unfiltered radiation is inadequate It is necessary to employ filtered radiation combined with radium element or radon implantations The factors used are 140 kv 5 ma , skin-focal distance of 10 inches (25 cms), and 3 mm Al filter At the base of the lesion or immediately under the lesion may be placed one or two gold radon implants of 2 mc each 1 cm apart Radium element needles may

be utilized in the same manner At the same time, the glands of the neck are irradiated It is customary to employ 200 kv , 5 ma , 10 to 20 inches (25 to 50 cms) skin-focal distance and a filter of 2 mm Cu. By the cross-fire method expose all the neck glands, giving 600 r to right and left lateral surfaces and to the anterior surface of the neck every other day for a total of six doses. By cross firing this amounts to a total of 3600 r

Radium by surface or interstitial application yields excellent results At the Memorial Hospital in New York City, gold-platinum tubes of radium are so embedded in a dental compound mold as to permit cross firing of the lesion. The average dose administered is 100 mg-hr per sq cm. of tumor surface. If the lesion is thick, this dose is fortified with gold radon implants of 2 mc. each inserted at the base of the lesion If glands are present, they may be treated by high-voltage x-rays or by radium bomb or pack.

Some prefer to use radium element needles For interstitial irradiation we have found gold radon seeds more convenient and more economical and our results have compared favorably with those obtained with radium element needles

Most surgeons prefer radical excision of the primary tumor and unilateral or bilateral dissection of the neck glands.

Our routine treatment for carcinoma of the lip consists of scalpel excision or destruction of the primary growth by electrosurgery The wound and the apparently normal tissues surrounding it, including a large portion of the chin, are treated with unfiltered radiation. A dose of 600 r is given every third day for four doses The x-ray treatment is started immediately after the completion of the operation. The gland-bearing areas of the neck are treated routinely with filtered x-rays A total of six erythema doses (3300 r) is given to the neck, two erythema doses to each of three portals of the neck. If metastatic nodes are present, then the x-rays are given according to the technic of Coutard

Intraoral Carcinoma —The treatment of carcinoma within the mouth is governed by the same general principles Therefore cancer of the tongue, buccal mucous membrane, floor of the mouth and palate will be discussed together. The radiosensitivity of the same histologic type of tumor within the mouth varies widely For example, carcinoma of the buccal mucous membrane usually undergoes late metastasis and the percentage of five-year cures is higher, whereas carcinoma of the tongue usually undergoes early metastasis and progresses rapidly. Carcinoma of the tongue is probably the most frequent, the most serious and the most rapidly developing carcinoma of the mouth. There is no satisfactory explanation for this except that perhaps the movement of the tongue because of its muscular structure aids the flow of lymph, thereby favoring the deposition of cancerous emboli.

The treatment of carcinoma of the mouth should begin with as perfect mouth hygiene as is possible to obtain Nonirritating mouth-

washes are to be used liberally. The teeth are to be cleaned and scaled. Carious, infected and jagged teeth should be removed. Too much trauma must not be permitted in carrying out this program of hygiene nor should there be any delay in the proper treatment of the carcinoma. A blood Wassermann test is done routinely. If the serologic reaction of the blood is positive and the biopsy examination shows unquestionably squamous-cell carcinoma, the malignancy is treated first. Treatment of syphilis with bismuth in the presence of mouth malignancy is not contraindicated. The arsenicals may be used after the eradication of the primary tumor.

Intraoral carcinoma must be treated in a hospital, as it is sometimes necessary to give hypodermoclyses or to feed by tube. Most of the patients require special nursing care. Surface radium irradiation or roentgen irradiation of the primary tumor is not feasible. In this connection, the Chaoul method of roentgen irradiation has been used successfully for the treatment of intraoral carcinoma. For lesions that are not too bulky, we prefer interstitial irradiation, using radon implants. After carefully measuring the lesion and sketching it, the number of seeds required are ordered. It is best to have on hand more than the calculated number of seeds. Insert the seeds around the tumor mass and beneath it. Each seed contains 1 to 2 mc. of radon. They are placed 1 cm. from each other with an instrument especially made for the purpose. If the growth is bulky, we prefer to remove the tumor mass by the cutting current or destroy it by electrocoagulation. Kaplan and Quick advocate electrosurgery combined with irradiation in preference to scalpel surgery in the treatment of carcinoma within the mouth. Simpson, on the other hand, prefers to use surface application of radon screened through 2 mm. lead and the interstitial application of lead seeds with a wall thickness of 0.3 mm. He does not consider it safe to use more than 35 mc. in any tongue lesion. Every effort is made to protect the normal tissues from overexposure to irradiation by the use of suitable plates made of lead and rubber or dental compound appropriately placed in the mouth.

The real problem in the treatment of malignancies of the mouth is the treatment of the lymphatics and nodes. The neck is treated whether or not nodes are palpable. If there are no palpable nodes give 1200 r to the right and left lateral surfaces and the anterior surface of the neck. A total dose of 3600 r is administered by cross firing to the neck over a period of two weeks. The factors used are 200 kv., 5 ma., *skin-focal distance of 10 inches (25 cm.) and a filter of 2 mm. Cu.* We employ the Coutard technic for the treatment of metastatic carcinoma.

With the large doses necessary to treat lesions of this type, certain complications are apt to occur following irradiation. Pain referred to the temporal region and involving the entire mouth is frequently noted. A later complication may be necrosis of bone, teeth and of the soft tissues. *A serious immediate complication is edema of the glottis*

Carcinoma of the Penis.—The same general principles outlined for the treatment of intraoral carcinoma are applicable to carcinoma of the penis. Surface or interstitial irradiation may be used combined with roentgen irradiation of the inguinal nodes. Amputation combined with irradiation is sometimes essential for a clinical cure. Occasionally, it is necessary to resort to gland dissection. An interesting thing to note is that cancer of the penis very seldom occurs in those who are circumcised early in life.

TABLE 32.—STATISTICAL THERAPEUTIC TABLE. SQUAMOUS-CELL EPITHELIOMA

Author	Date	Location	No of cases	No of cases with metastasis	Period of observation	Therapeutic method	Cures
Bloodgood	1914	Lip				Surgery	62.5%
Broders	1920	Lip	537	No glands		Surgery and radiation	76.26%
Lain	1922	Lip				Radium	97.7%
Brewer	1923	Lip				Surgery	64.0%
Lane Claypon	1930	Lip			5-yr survivals	Surgery	62.0%[1]
						Radiation	71.1%
Lane-Claypon	1930	Tongue			3 yrs	Surgery	20.25%[2]
						Radiotherapy	37.8%
Wangensteen and Randall	1930	Lip	99		5 yrs	Surgery and radiation	7.0%
Simeoni	1930	Lip	200		3 yrs	Operation	49.0%
Simeoni	1930	Mouth	102		7 mos to 10 yrs	Surgery	14.0%
Simeoni	1930	Tongue	157		3 yrs	Surgery	19.7%
Pfahler	1930	Mouth	94			Radiation	60.0%
Falchi	1930		9		7 mos to 2 yrs	Electrocoagulation	66.0%
Regaud		Tongue and mouth	344	Only 20% operable	3 yrs or more	Radium	23.8%
Quick		Mouth and lip	2741		3 yrs	Radiation and surgery	11.8%
Martin		Lip	119		5 yrs	X-rays	87.0%
Halberstaedter and Simons	1931	Skin	556			Radium mostly, no surgical diathermy	60.0%
Taylor	1931	Tongue, mouth	160			Electrosurgery, scalpel surgery and radium	23.7%
Simmons	1931	Mouth	73		5 yrs	Scalpel and electrosurgery	38.0%
Pfahler and Vastine	1932	Lip	179		5 yrs	Electrosurgery and irradiation	85.5%
Elliott	1933	Lip	66		5 yrs	Electrosurgery and irradiation	63.6%
Kelly	1933	Lip	99		5 yrs	Radium	72.7%
Zeisler	1933	Mouth, lip, and skin	102		1 to 5 yrs	Surgery, electrosurgery and radiation	71.0%
Schreiner	1933	Group I skin	104		5 yrs	Surgery, electrosurgery and radiation	54.8%
Schreiner	1933	Group II skin	60		5 yrs	Surgery, electrosurgery and radiation	6.6%
Traub and Tolmach	1933	Skin	26		2 mos to 5 yrs	Electrosurgery and radiation	80.8%
Schreiner and Mattick	1933	Lip	163		5 yrs	Radiation	47.0%
Schreiner	1933	Lip	118	Nodes, inoperable	5 yrs	Radiation	11.1%
Lund and Holton	1933	Lip	147 primary 47 recurrences			Surgery (excision)	66.0%
Rose and Phillips	1933	Mouth	192		2 yrs	Radium	37.0%
Kennedy	1934	Lip	246	80%	5 yrs	Scalpel surgery	67.0%
Wile and Hand	1937	Lip	308			Surgery	37.8%
						Radiotherapy	37.0%

[1] Summary of studies based on statistics found in the literature
[2] Quoted by Lane-Claypon

Statistics — A detailed exposition of the statistics of cancer survivals and deaths would be out of place in a work of this type. The statistics will be presented in the form of a table compiled from the literature. For details, the reader is advised to read the original articles. The statistical study of Janet Lane Claypon is especially recommended.

Comments on Statistics — The statistics quoted are not such as to cause elation. Many of the reports, especially those dealing with radium, relate mostly to inoperable, almost hopeless cases. The high percentage of cures obtained by some authors is due largely to the fact that the cases were favorable ones.

It appears from the study of the available statistics that early carcinoma of the mouth, lips, and squamous cell carcinoma of the skin respond equally well to destructive measures regardless of what agent is used and provided that metastases were absent when treatment was instituted. There is some difference of opinion on this point. Lane-Claypon shows that treatment with irradiation yields better results than treatment with surgery. On the other hand, Wile and Hand state that the results of treatment of early cancer of the lip were excellent with surgical removal plus dissection of the regional lymph nodes, good with surgical excision alone or with radium therapy and only fair with roentgen therapy. This makes it necessary to emphasize at this point the fact that carcinoma must be treated only by one who is qualified by training and experience, and who is properly equipped.

The statistics confirm the fact that carcinoma of the lip is probably the least malignant of all cancers affecting the oral mucosa. In early cases the expectancy of five-year cures is approximately 75 per cent. Carcinoma of the buccal mucosa is no more malignant than carcinoma of the lip. To the other extreme, the statistics show that carcinoma of the tongue is probably the most malignant of all mouth cancers with an expectancy of five-year cures of approximately 20 per cent. Carcinoma of the floor of the mouth is also very malignant.

The best statistics are shown by those authors who employed radiotherapy combined with surgical treatment. There is a large number of articles dealing with surgical methods combined with irradiation.

The successful results obtained in early or favorable cases with radical treatment demands that attention be focussed on early diagnosis and the institution of immediate and radical treatment. At the present writing we regard well-developed prickle cell epithelioma of the skin or the mucosa a disease that should receive immediate surgical treatment combined with irradiation. There is reason to believe that preliminary and especially postoperative irradiation at the site of the lesion and also irradiation of the lymphatics that drain the region of the lesion is of service in completely eradicating the disease. Certainly, irradiation should be employed in all inoperable cases. Radium experts are obtaining excellent results in operable cases as shown by the subjoined statistics. But the dermatologist should not attempt

such work without adequate experience and equipment. Radium, properly employed, seems to produce better results in cancer of the

FIG. 304.—Keratosis of the mucous membrane of the lip with underlying infiltration, an early prickle-cell epithelioma

FIG. 305.—Same as Fig. 304, after two strong x-ray treatments. Total dose was probably 1200 r. No recurrence in ten years.

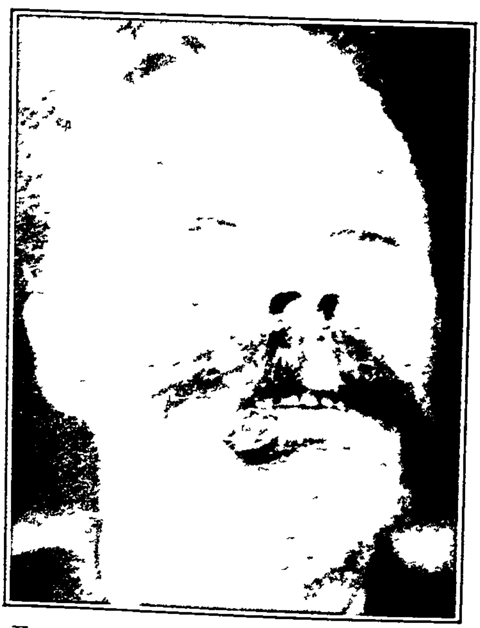

FIG. 306.—A well-developed prickle-cell epithelioma of the lip, without palpable glands in the neck. Photograph taken in 1903. (Courtesy of Dr. W. A. Pusey.)

FIG. 307.—Same patient as shown in Fig. 306 after x-ray treatment. This photograph was taken in 1912. (Courtesy of Dr. W. A. Pusey.)

mucous membrane of the cheek than does surgery. A combination of surgical diathermy and radium offers the best chance of success in such cases.

The occasional excellent results obtained in inoperable cases with radium and *x* rays warrants the use of these agents in all such cases. The results obtained in apparently hopeless cases with a combination of surgical diathermy, *x* rays and radium by Pfahler, Clarke and others should make one refuse to consider a case as positively incurable until this method has been given a trial.

METASTATIC CARCINOMA

Secondary cutaneous epithelioma may be the result of metastasis from a primary visceral lesion, a lesion of the breast or a primary skin tumor. Such cutaneous epitheliomas occur as multiple, deep-seated firm nodules. These lesions are more susceptible to irradiation than are the parent lesions. They should be treated with the intensive filtered technic described in the previous section under Squamous Cell Epithelioma.

There is a type of secondary cutaneous epithelioma known as cancer *en cuirasse*, also lenticular carcinoma and carcinomatous lymphangitis. It is extremely resistant. The senior writer has treated 4 advanced cases of this type without benefit. In 2 early cases the process was temporarily arrested.

PAGET'S DISEASE

Fordyce (1904) was the first to report the use of *x*-rays in Paget's disease. The lesion was in the gluteal region and the diagnosis was confirmed by biopsy. The lesion was cured by fractional treatment and there was no recurrence. Hartzell (1906) reported the clinical cure of 2 cases of Paget's disease of the breast. In one patient mammary carcinoma developed during treatment and in the other patient there was a suspicious nodule in the breast several months after the cutaneous lesion had disappeared. The technic was fractional. In the same year *Bisserie reported the cure of 7 out of 9 cases with intensive technic*. Taylor (1907) cured a case of Paget's disease of the breast with fractional treatment but mammary carcinoma developed during the treatment. Jackson cured a case of extramammary Paget's disease—the lesion was on the cheek. Belot, Terzaghi and Campana, Sequeira and others have reported the successful treatment of Paget's disease of the breast. Boggs states that he has cured a number of cases of Paget's disease of the breast. Several of the patients have remained well for ten years. The entire breast and axilla were included in the fields of irradiation.

There is a difference of opinion as to whether Paget's disease begins as a degeneration in the skin or whether the cutaneous manifestations are secondary to cancer of the underlying or neighboring tissue. Pautrier read an excellent paper on this subject before the section on Dermatology and Syphilology of the American Medical Association in May, 1927. The gist of Pautrier's opinion is as follows:

1. That the Paget cell cannot be regarded as a dyskeratotic cell in the same group as that found in Darier's disease, in molluscum contagiosum, and in other dyskeratoses, but is distinctly and always a cancer cell

2 That the examinations of extremely early cases, in which the breast has been extirpated, show mammary cancer to be present and therefore, the process is not from without inward, but rather from within outward, the skin changes being secondary to the gland cancer.

3 Pautrier has shown that extramammary cases of Paget's disease are associated with cancer of adjacent structures. Thus, Paget's disease of the scrotum has been associated with rectal cancer, and Paget's disease of the arm associated with nevocarcinoma.

From their studies of Paget's disease of the nipple, Darier and Fraser agree with the opinion expressed by Pautrier that Paget's disease of the nipple is an intracanalicular carcinoma from the very beginning and that the cutaneous manifestations start concurrently with those of the mammary structures Paget's disease of the nipple occurs rarely in men and has the same serious prognosis as that occurring in the female breast. The disease may be bilateral and it seldom occurs before the age of thirty-five years. Metastasis occurs late as a rule, but it may start early.

Extramammary Paget's disease has been described as occurring on the penis, scrotum, perineum, pubic region, umbilicus, lip, nose, forearms, trunk and ears.

Technic.—We are opposed to *x*-ray or radium treatment for Paget's disease The thought that should be uppermost in the mind of the reader is to consider even very early Paget's disease of the breast as a carcinoma of the mammary gland The treatment should then be directed towards the removal of every single malignant cell This can be accomplished, in our opinion, only by mastectomy, including the removal of the axillary nodes followed by high-voltage irradiation of the lymph-node-bearing areas If the patient is in poor physical condition and operation is contraindicated, roentgen therapy may be used according to the technic of Coutard The important thing in irradiation is to treat the whole breast and the whole chain of lymphatics

BOWEN'S DISEASE

Bowen's disease has been described as a precancerous dermatosis Histologic studies show that it is an intra-epidermic carcinoma Some cases may infiltrate beyond the basal-cell layer and may eventuate into basal, squamous or mixed basal-squamous-cell epithelioma. Bowen's disease, it is believed, does not metastasize, but if squamous-cell epithelioma forms, then this latter condition is capable of doing so. Bowen's disease usually occurs on the skin The literature contains over 52 cases of Bowen's disease affecting mucous membranes, especially those of the genitals.

Fig 308

Fig 309

Fig 308 —Bowen's disease of the perianal area of twenty years duration Diagnosis confirmed by biopsy examination This lesion recurred after incomplete surgical removal

Fig 309 —Same as Fig 308 showing partial involution of the lesion after x ray treatment

Fig 310 —Same as Fig 308 showing complete involution of the lesion several months after completion of x ray therapy *The patient received two treatments each week for four weeks* Each treatment consisted of 500 r of medium voltage (100 kv) lightly filtered (3 mm Al) x rays

Technic.—This disease often responds favorably to radium or roentgen irradiation as described for basal-cell epithelioma. We prefer scalpel excision or electrosurgical destruction.

MELANOCARCINOMA.

The term melanoma is used to designate any abnormal collection of melanin—pigmented cells. Melanoma may be benign or malignant An example of a benign melanoma is a pigmented nevus. Malignant melanomas are of two types—the melanocarcinomas and melanosarcomas. The word melanoma is frequently used without a suffix and when so used it designates melanocarcinoma. Malignant melanoma (melanocarcinoma) arises from nevi and melanosarcoma arises from the blue nevus of Tièche and the choroid plexus of the eye. These lesions are extremely malignant. Metastases occur early.

A study of the statistics indicates that relatively few patients with melanomas live beyond three years after their removal Butterworth and Klauder in a recent article point out that the largest percentage of three-year cures were obtained in the group that was treated by a combination of excision and irradiation. These authors report a series of 32 cases with 10 survivals after three years.

Technic.—It is important that benign melanomas be properly treated to prevent their transformation into malignant melanomas. In spite of occasional good results, it is our opinion that irradiation alone by any technic should not be relied upon for the cure of these lesions. The local lesion must first be thoroughly and widely excised by scalpel or electrosurgical cutting The wound should then be treated with high-voltage *x*-rays employing 200 kv. and at least 1 mm. Cu. At the same time, the regional nodes and lymphatics should be treated with equal vigor.

SARCOMA.

Sarcomas of the skin are the least common of the cutaneous malignancies. They may be pigmented or nonpigmented. The cells which make up these tumors may be of the small or large round variety, spindle-shaped or the mixed-cell type. The small round-cell pigmented sarcomas are the most malignant and the fibrosarcomas and giant-cell sarcomas the least malignant. They may be localized or multiple.

Cases of melanosarcoma of the skin are rare and usually are metastases from sarcoma of the eye. Rarely, they develop from the blue nevus of Tièche. These are very malignant. Metastasis is seen early as a rule

Neurogenic Sarcoma.—These tumors arise from nerve tissue and are sometimes seen following surgical excision of a neurofibroma in von Recklinghausen's disease. After removal, they have a tendency to recur along the nerve trunk. The mortality is high.

Melanotic Whitlow (Melanoblastomas of the Nailbed) —This is a malignant disease of the nail bed, which is characterized by the formation of nodules associated with melanin about the border and beneath the nail The lesions are painful as a rule

FIG 311 —Melanoma Note the outlying satellites Patient referred by the late Dr J C Johnston

Dermatofibrosarcoma —This condition was first described by Darier in 1924 Infiltrated plaques from which project pedunculated nodules and tumors may appear anywhere on the skin These lesions are asymptomatic benign and do not cause metastases as a rule Lesions of dermatofibrosarcoma may recur after their removal

FIG 312 —Same patient shown in Fig 311 after several intensive x ray treatments There was a relapse in a few months Two hyperintensive filtered treatments were then given There has been no recurrence since November 1914

Lymphosarcoma —These tumors arise in a single chain of lymph glands They are very malignant and show metastases early The cervical and axillary glands are most frequently involved Ulcerations are frequently seen in late cases

Technic —The sarcomas as a group are radioresistant, except the lymphosarcomas The multiple metastatic sarcomas can be treated as a rule, only by intensive roentgen irradiation These lesions are

often inoperable Single lesions of melanosarcoma, melanotic whitlow, neurogenic sarcoma and of lymphosarcoma are sometimes cured by regional and local irradiation combined with surgical removal Coley's serum may be used as an adjuvant to irradiation and surgery in all sarcomas. The technical details for the treatment of these tumors are the same as those for squamous-cell epithelioma. The protracted high voltage, heavy filtration, low intensity method of roentgen irradiation is the method of choice.

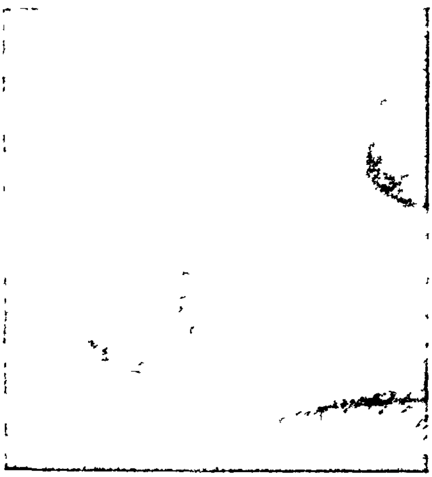

FIG 313 —Melanoma before radium treatment

FIG 314 —Same as Fig. 313 after intensive treatment with beta rays of radium No recurrence in five years

Abbe has found radium to be a specific in the giant-cell type and this agrees with the writers' experience. Fibrosarcoma and lymphosarcoma yield readily to both x-rays and radium (Pfahler, Janeway and others) Bisserié treated 8 cases of diffuse sarcoma with x-rays and obtained 100 per cent clinical cures. There were no recurrences for fifteen months. Belot cured 2 similar cases. We have not been so fortunate This type of sarcoma is usually a round-cell growth which begins in the subcutaneous tissue and involves the skin secondarily It may be a primary growth or it may be the result of metastasis from a primary tumor in the skin or some other tissue The type is very malignant We have treated 6 cases with x-rays In 4 instances there were subcutaneous nodules scattered over the body which occurred subsequent to excision of a single cutaneous tumor The individual nodules disappeared as a result of one or two hyperintensive filtered doses, but new nodules continued to appear until the patient died or discontinued treatment. The same result was obtained in 1 patient who was treated with radium gamma rays. One patient who exhibited three ulcerating tumors (round-cell type) made a complete recovery (x-rays) and there was no recurrence for two years.

Bisserié treated 12 cases of melanosarcoma with massive doses of

x rays All were clinically cured, but there were 5 recurrences We have cured 4 cases of primary melanosarcoma with x rays without recurrence for from four to twelve years There was complete failure

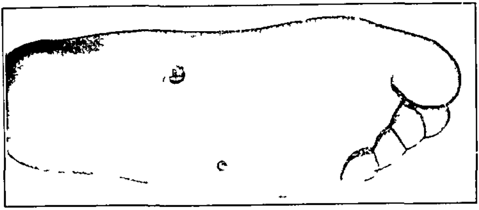

Fig 315 — A rapidly growing sarcoma occurring in a patient who had lesions of sarcoma of the Kaposi type

in two primary tumors In 4 cases of multiple secondary tumors the individual tumors resolved under treatment but the patients died from pulmonary sarcomatosis

Fig 316 —Same as Fig 315 after one hyperintensive x ray treatment Total dose was probably 600 r

Kaposi's Sarcoma (Idiopathic Multiple Hemorrhagic Sarcoma)—This cutaneous entity can be kept under control more or less indefinitely with x-rays or radium It is even possible to cure some cases permanently Irradiation is the method of election although there

is no harm in combining with other forms of treatment such, for instance, as the administration of arsenic. Under the influence of irradiation the individual plaques and tumors will disappear, but new lesions may continue to develop. Both fractional and intensive doses have been successful Subintensive doses are to be preferred.

Hartzell, Williams, Halle, Lustgarten, Grigoryev, Bulkley, Gilchrist and Ketron, and many others, have reported good results with x-rays We have treated a large number of cases with filtered and unfiltered x-rays and some with gamma and beta rays of radium. The result was splendid in most of the patients However, new lesions continued to develop at other sites and also in the treated areas It is advisable to use the smallest amount of irradiation that will cause involution of the lesions. The reader may read the authors' article on Kaposi's sarcoma for a complete description of the disease and its treatment by irradiation (see Bibliography).

BIBLIOGRAPHY

ABBE, R Radium as a Specific in Giant Cell Sarcoma, Med Rec , **77**, 1, 1910

ALLEN, C W Radiotherapy in Cancer and Skin Diseases, New York State Jour Med , **2**, 176, 1902

BECK, C The Pathological and Therapeutic Aspects of the Effects of the Roentgen Rays, Med Rec , **61**, 83, 1902

BELOT, J Treatment of Diffuse Cutaneous Sarcoma, Premycosis and Mycosis Fungoides by Radiotherapy, Arch Roentg Ray, **9**, 139, 1904–1905

——— Quelques applications de la radiothérapie à la dermatologie, Bull Soc franç de dermat et syph , **17**, 331, 1906

——— Treatment of Paget's Disease by Radio-therapy, Arch Roentg Ray, **12**, 67, 1907

——— Le traitement radio-chirurgical de l'épithélioma cutané, Médecine, **1**, 540, 1919-1920

BISSERIÉ, F The Treatment of Superficial Malignant Neoplasms by Radio-therapy, Arch Roentg Ray, **11**, 142, 1907

BLOODGOOD, J C Cancer of the Tongue Based Upon the Study of Over 100 Cases, Trans Am Surg Assn , **32**, 372, 1914

——— Carcinoma of the Lower Lip, Its Diagnosis and Operative Treatment, Surg , Gynec and Obst , **18**, 404, 1914

BOGGS, R H The Treatment of Epithelioma of the Lower Lip, Interstate Med Jour (Suppl Roentgenol), **23**, 114, 1916

——— The Treatment of Epithelioma by Radium, Am Jour Med Sci , **158**, 87, 1919

BOWEN J T Precancerous Dermatoses A Study of Two Cases of Chronic Atypical Epithelial Proliferation, Jour Cutan Dis , **30**, 241, 1912

BREWER, G E Carcinoma of the Lip and Cheek, Surg , Gynec and Obst , **36**, 169, 1923

BRODERS, A C Squamous-Cell Epithelioma of the Lip, Jour Am Med Assn , **74**, 656, 1920

——— The Grading of Carcinoma, Minnesota Med , **8**, 726, 1925

BULKLEY, L D Multiple Idiopathic Sarcoma, Hands, Feet and Ears (Kaposi Type) Subsidence of the Disease Under X-Ray Treatment, Jour Cutan Dis , **24**, 530, 1906

BURROWS, A A Report of the Work of the Manchester and District Radium Institute, from January 1 to December 31, 1917, Radium, **11**, 17, 1918

——— Report of the Work from January 1 to December 31, 1919, Radium, **16**, 1, 1923

BUTLIN H T The Results of Operations for Carcinoma of the Tongue, with an Analysis of 197 Cases, Brit Med Jour , **1**, 1, 1909

BUTTERWORTH, T , and KLAUDER, J V Malignant Melanomas Arising in Moles, Jour Am Med Assn , **102**, 739, 1934

Cancer A Manual for Practitioners Published by the Committee on Publication Representing the Massachusetts Medical Society and the American Society for the Control of Cancer Boston 1940

Cipollaro A C and Foster P D Bowen s Precancerous Dermatosis of the Mucous Membrane New York State J Med 40 264 1940

Cole H N and Driver J R Radium Dosage and Technique in Carcinoma of the Skin Am Jour Roentgenol 33 652 1935

Coutard H Roentgen Therapy of Epitheliomas of the Tonsillar Region Hypopharynx and Larynx from 1920 to 1926 Am Jour Roentgenol 28 313 1932

Cutler M The Problem of Radiosensitivity Jour Am Med Assn 103 1204 1934

Dachtler H W Roentgenological Treatment of 530 Cases of Malignant and Other Tumors of the Face Am Jour Roentgenol 4 599 (Jan) 1917

Daland E M End Results of Radium Treatment of Skin Cancer Jour Am Med Assn 86 471 1926

Darier J Dermatofibromes progressifs et recidivants ou fibrosarcomes de la peau Ann de dermat et syph 6 ser 5 545 1924

Dean A L Jr The Treatment of Epithelioma of the Penis with Radium and Roentgen Rays Am Jour Roentgenol 15 36 1926

Desjardins A U Radiosensitiveness of Cells and Tissues and Some Medical Implications Arch Surg 25 926 1932

Dolloway L M Results in the Treatment of 150 Cases of Superficial Epitheliomas Am Jour Roentgenol 4 619 1917

Dresser S and Dumas C E Treatment of Cancer of the Skin by Divided Doses of High Voltage Roentgen Rays Am Jour Roentgenol 36 332 1936

Duane W and Greenough R B Report of Results of Radium Treatment at the Collis P Huntington Memorial Hospital by the Cancer Commission of Harvard University Boston Med and Surg Jour 177 359 1917

Duncan J H The X Ray as a Therapeutic Agent Classified Report of 43 Cases Interstate Med Jour 9 531 1902

Ewing J Neoplastic Diseases 4th ed Philadelphia W B Saunders Company 1940

——— Radiosensitivity Radiology 13 313 1929

Ferguson Interstate Med Jour 9 265 1902

Fordyce J A A Case of Paget s Disease of the Gluteal Region Cured by the X Ray Jour Cutan Dis 22 382 1904

——— Paget s Disease (?) of the Gluteal Region the Effect of the Roentgen Ray Upon the Disease Jour Cutan Dis 23 193 1905

——— in discussion on Stelwagon H W Additional Observations on the Use of Rontgen Rays in Dermatology Jour Cutan Dis 24 105 1906

Forssell G *Experiences in the Permanency of Radiological Cure in Cancer* Am Jour Roentgenol 12 301 1924

Fraser J F Bowen s Disease and Paget s Disease of the Nipple Their Relation to Dyskeratosis Arch Dermat and Syph 18 809 1928

Gardner R A Radiation Therapy of Tongue Carcinoma Brit Med Jour 2 1090 1935

Gilchrist T C and Ketron L W Report of Two Cases of Idiopathic Hæmorrhagic Sarcoma (Kaposi) Jour Cutan Dis 34 429 1916

Greenough R B Radium in the Treatment of Carcinoma of the Buccal Cavity Boston Med and Surg Jour 178 598 1918

Groigoryev Multiple Idiopathic Hæmorrhagic Sarcoma of the Skin (Kaposi) Russk J Kojn e Ven Bolezn 29 3 1915 Abstract Jour Cutan Dis 34 626 1916

Hahn Cited in Schiff E Treatment of Epithelioma With Roentgen Rays Arch Roentg Ray 12 276 1908

Halberstaedter L and Simons A Klinische und therapeutische Erfahrungen beim Hautkrebs Ztschr f Kreb forsch 32 146 1930

Halle Sarcoma Idiopathicum Multiplex Hæmorrhagicum Jour Cutan Dis 23 415 1905 (Abstract)

Harrison I C Radium Treatment of Skin Cancer Canad Pract 49 169 1924

Hartzell M B Idiopathic Multiple Hæmorrhagic Sarcoma (Kaposi) Jour Cutan Dis 26 97 1908

Hazen H H Prickle Cell and Basal Cell Skin Cancers Jour Am Med Assn 64 958 1915

——— Skin Cancer St Louis The C V Mosby Company 1916

——— Basal Celled Cancers of the Skin South Med Jour 10 241 1917

——— The Roentgen Ray *Treatment of Cutaneous Cancer South Med Jour* 12 87 1919

HAZEN, H H Roentgen-Ray Treatment of Cutaneous Cancer, Jour Am Med Assn, 76, 1222, 1921

——— The Roentgen-Ray Treatment of Diseases of the Skin, Am Jour Roentgenol, 9, 247, 1922.

——— Roentgen-Ray Treatment of the Bowen Type of Skin Cancer, Am Jour Roentgenol, 14, 450, 1925

HAZEN, H H, and WHITMORE, E R The End Results in Roentgen-Ray Treatment of Cutaneous Cancer, Am. Jour Roentgenol, 13, 141, 1925

HOLLANDER, L, and SHELTON, J. M The Intraoral Use of Superficial X-rays A Report of the Use of the Chaoul Tube, read at Section of Dermatology and Syphilology, Am Med Assn, Atlantic City, June 11, 1937, Arch Dermat. and Syph, 37, 279, 1938

HOPKINS, G. G The Treatment of Carcinomatous Growths by Roentgen Rays, Philadelphia Med Jour, 9, 626, 1902

JACKSON, G T [Epithelioma (Paget's Disease ?) of Cheek], Jour Cutan Dis, 30, 286, 1912

JANEWAY, H H Radium Therapy in Cancer at the Memorial Hospital, New York, Paul B Hoeber, Inc, 1917, pp 212, 223

——— The Treatment of Cancer of the Lip by Radium A Report of 21 Cases, Jour Am Med Assn, 70, 1051, 1918

——— Treatment by Radium of Cancerous Mucous Membranes, Am Jour Roentgenol, 5, 414, 1918

JOHNSON, W, and MERRILL, W H The X-rays in the Treatment of Carcinoma, Philadelphia Med Jour, 6, 1089, 1900

——— The X-ray Treatment of Carcinoma, Am Med, 4, 217, 1902

KAPLAN, I I Radiation Therapy of Malignancy of the Tongue, Am Jour Surg, 30, 227, 1935

KELLY, E Radium Therapy in Carcinoma of the Lip, Jour Am Med Assn, 100, 388, 1933

LAIN, E S A Clinical Study of Epithelioma of the Lower Lip, Jour Am Med Assn, 75, 1052, 1920

——— Treatment of Cancer of the Lip by Radiation, Arch Dermat and Syph 6, 131, 1922

LAMMERS, H Radium Treatment of Cancer of the Lip, Acta radiol, 2, 197, 1923-1924

LANE-CLAYPON, J Report on Cancer of the Lip, Tongue and Skin, London, 1930 (Great Britain Ministry of Health Reports on Pub Health and Med Subj, No 59)

LUSTGARTEN, S Sarcoma Pigmentosum Idiopathicum (Kaposi), Jour Cutan Dis, 23, 171, 1905

MACKEE, G M, and CIPOLLARO, A C Idiopathic Multiple Hemorrhagic Sarcoma (Kaposi), Am Jour Cancer, 26, 1, 1936

——— Cutaneous Cancer and Precancer, New York, Paul B Hoeber, 1937

MARTIN, H E Radiation Therapy in Skin Cancer, Am Jour Cancer, 19, 605, 1933,

MONTGOMERY, H Basal Squamous Cell Epithelioma, Arch Dermat and Syph, 18, 50, 1928

MORTON, W J The Treatment of Malignant Growths by the X-ray, Med Rec, 61, 361, 1902

PACK, G T, and LIVINGSTON, E M Treatment of Cancer and Allied Diseases, New York, Paul B Hoeber, 1940

PADGETT, E C Principles Pertinent to the Radiation Therapy of Oral Cancer With Methods of Calculating Dosage, Internat Jour Orthodontia, 22, 716, 1936

PAGET, SIR J On Disease of the Mammary Areola Preceding Cancer of the Mammary Gland, St Barth Hosp Rep, 10, 87, 1874

PAUTRIER, L M "Paget's Disease of the Nipple," Arch Dermat and Syph, 17, 767, 1928

PETERS, W Zur Statistik des Zungencarcinoms, Deutsch Ztschr f Chir, 154, 289 1920

PFAHLER, G E The Treatment of Sarcoma by Means of the Roentgen Rays, New York Med Jour, 86, 1153, 1907

——— Fibrosarcoma, Jour Cutan Dis, 35, 102, 1917

PFAHLER, G E, and VASTINE, J H The Treatment of Cancer of the Lip by Electrocoagulation and Irradiation, Jour Am Med Assn, 98, 32, 1932

Pinch, A E H Report on the Work Carried Out at the Radium Institute, London, from January 1 to December 31, 1917 [illegible] 11 43 1918
——— ——— from January 1 to December 31 1918 [illegible] 12 11 1919
——— ——— from January 1 to December 31 1919 [illegible] 15 [illegible] 1920
Pusey W A and Caldwell E W The Practical Application of the Roentgen Rays in Therapeutics and Diagnosis [illegible] W B Saunders Company 1904 p 467
Quick, D Radium in the Treatment of Epithelioma of the Lips Jour [illegible] 1921
——— The Practical Application of Radium [illegible] New York State Jour Med 33 [illegible] 1933
Quigley D T The Treatment of Superficial Cancer With Statistics and Technique Am Jour Roentgenol 10 [illegible] 1923
Regaud C Principes du traitement des épithéliomas [illegible] Jour de radiol et d électrol 7 297 1923
——— Radium Therapy of Cancer at the Radium Institute of Paris Am Jour Roentgenol 21 1 1929
Rinehart J F Treatment of Epithelial Skin Cancers and Senile Keratoses with the X ray Philadelphia Med Jour 9 [illegible] 1902
Scholtz, W Ueber den Einfluss der Röntgenstrahlen auf die Haut in gesundem und krankem Zustand Arch f Dermat u Syph 59 421 1902
Schreiner, B F and Brown H F R An Investigation of the Results Obtained in Cancer of the Tongue Treated by Radium and Roentgen Rays Am Jour Roentgenol 15 207 1926
Schreiner, B F and Kress L C Contribution to the Treatment of Cancer of the Lip by Irradiation Report on 156 Cases Jour Cancer Res 8 [illegible]21 1924
Schreiner, B F and Mattick W L Five-year End Results Obtained by Radiation Treatment of Cancer of the Lip Am Jour Roentgenol 30 67 1933
Schreiner B F Simpson B T and Mueller I Diagnosis and Treatment of Basal Cell Epithelioma Am Jour Surg 33 1 1919
Schultz F X ray Treatment of Skin Diseases New York Rebman Company 1912 p 151
Senear F E Andrews I and Willis D A Progressive and Recurrent Dermatofibrosarcoma Arch Dermat and Syph 17 [illegible]1 1928
Sequeira J H A Preliminary Communication on the Treatment of Rodent Ulcer by the X rays Brit Med Jour 1 332 1901
——— [Rodent Ulcer] Brit Med Jour 2 [illegible]1 1901
——— Treatment of Cancer by Radiotherapy and by Radium Arch Roentg Ray 14 [illegible] 1909
Shelmire B and Fox L C Small Radium Needles in Treatment of Malignant Cutaneous Tumors Arch Dermat and Syph 34 [illegible] 1936
Sherwell S The Technic of an Efficient Operative Procedure for the Removal and Cure of Superficial Malignant Growths New York State Jour Med 8 301 1908
——— Further Observations on the Technique of an Efficient Procedure for the Removal and Cure of Superficial Malignant Growths Jour Cutan Dis 28 187 1910
Simmons C C [The Treatment of Carcinoma of the Skin With Radium The Results in the Cases Treated at the Collis P Huntington Memorial Hospital] Boston Med and Surg Jour 181 477 1919
——— The Treatment of Oral Cancer Am Jour Roentgenol 20 5 1931
Simpson F L Radium Therapy St Louis The C V Mosby Company 19[illegible] p 188
——— Radium Dosage and Technique in Carcinoma of the Tongue Am Jour Roentgenol 34 (3) 1935
Simpson F E and Flesher R L Radium Emanation in the Treatment of Cancer of the Tongue and Other Parts of the Oral Cavity Am Jour Roentgenol 15 201 1926
Stenbeck T Ein Fall von Hautkrebs geheilt durch Behandlung mit Röntgenstrahlen Mitt a d Grenzgeb d Med u Chir 6 317 1900
Stern S Report of 800 Dermatological Cases Treated With X rays and High Frequency Currents at the Mount Sinai Hospital J Cutan Dis 25 459 1907
Stevens J T Statistics and Technique in the Treatment of Superficial Malignancy With Radium Roentgen Rays and Electrothermic Coagulation Am Jour Roentgenol 11 241 1924
Stewart F W Radiosensitivity of Tumors Arch Surg 27 979 1933

Sweitzer, S E An Analysis of 43 Cases of Skin Cancer, Jour Am Med Assn, **69**, 179, 1917

Taussig, L Carcinoma of the Tongue and Its Treatment With Radium, Arch Dermat and Syph, **6**, 424, 1922

Taylor, G S [Treatment of Rodent Ulcer], Brit Med Jour, **2**, 852, 1901

Taylor, G W Cancer of Lip and Mouth, Am Jour Cancer (Suppl), **15**, 2380, 1931

Taylor, J A Case of Paget's Disease Treated by *X*-rays, Arch Roentg Ray, **12**, 100, 1907–1908

Terzaghi, R, and Campana The Effects of Roentgen Rays on Paget's Disease of the Breast, Jour Cutan Dis, **26**, 123, 1908

Wangensteen, O H, and Randall, O S Treatment and Results in Carcinoma of the Lip, Am Jour Roentgenol, **30**, 75, 1933

Widmann, B P Unfiltered Roentgen Rays for Superficial Cancers of Wide and Deep Involvement, Am Jour Roentgenol, **28**, 526, 1932

Wile, U J, and Hand, E A Cancer of the Lip, Jour Am Med Assn, **108**, 374, 1937

Williams, C M *X*-ray Treatment of Cutaneous Epithelioma, Am Jour Med Sci, **129**, 465, 1905

——— Late Results of the *X*-ray Treatment of Cutaneous Epithelioma, Med Rec, **70**, 907, 1906

Williams, E G Report of Cases of Cancer Treated With the *X*-ray, Trans Am Roentg Ray Soc, **8**, 34, 1907

Williams, F H A Further Note on the Treatment of Epidermoid Cancer, Boston Med and Surg Jour, **144**, 329, 1901

Williams, F H, and Ellsworth, S W Treatment of Superficial New Growths by Pure Radium Bromid, Jour Am Med Assn, **60**, 1694, 1913

Williams Sarcoma Cutis Hæmorrhagica, Jour Cutan Dis, **26**, 40, 1908

Zeisler, E P Cancer of the Skin, Surg, Gynec and Obst, **56**, 472, 1933

CHAPTER XL

MISCELLANEOUS CUTANEOUS DISEASES *

The diseases discussed in this chapter are

1	Addison's Disease	14	Trachoma
2	Dermatitis Herpetiformis	15	Synovial Lesions of the Skin
3	Epidermolysis Bullosa	16	Elephantiasis
4	Pemphigus	17	Fordyce's Disease
5	Herpes	18	Fordyce-Fox Disease
6	Pityriasis Rosea	19	Leprosy
7	Pityriasis Rubra Pilaris	20	Lichen Nitidus
8	Raynaud's Disease	21	Purpura Hæmorrhagica
9	Scleroderma	22	Molluscum Contagiosum
10	Acrodermatitis	23	Sebaceous Cyst
11	Urticaria	24	Hydradenitis Suppurativa
12	Urticaria Pigmentosa	25	Mucous Retention Cyst (Sutton)
13	Lichen Urticatus		

ADDISON'S DISEASE

Ratera reports the cure of two cases of Addison's disease with x rays The first patient had a roentgenologic examination of the kidneys Subsequent to this examination, the constitutional symptoms and the pigmentation disappeared The second patient received x ray treatment the exposures being confined to the kidney regions, and consisting of monthly, cross-fire, filtered radiation The general symptoms disappeared rather promptly There was a gradual disappearance of the pigmentation

Golubinin reports one case The patient received daily exposures to the renal region for 25 treatments There was improvement in all symptoms The weight increased, the heart action became more regular, the digestive disturbances disappeared and the bronzing became less conspicuous

Rieder, Wiesner, and Piccinino also report one case each, in which, following irradiation of the adrenals, there was disappearance of the pigmentation of the skin and mucosæ of headaches and muscular asthenia together with marked subjective improvement In Piccinino's case there was also a substantial increase in weight

Popp recommends roentgen therapy in Addison's disease, when other therapeutic methods have failed He reports a case which showed substantial improvement lasting four months when following a

* In the last edition this chapter was revised by Dr Franklin H Grauer Some of the material added by Dr Grauer has been retained in this edition

severe emotional shock, the patient suddenly died The patient had received three *x*-ray treatments of $\frac{1}{4}$ erythema dose to each adrenal There was an interval of four weeks between the first and second treatment, and twelve weeks between the second and third The tube was at the level of the twelfth rib. The factors were 3 ma, Sp G, 30 cm., distance, 23 cm The filtration consisted of 0 5 mm. of zinc and 2 mm of aluminum

DERMATITIS HERPETIFORMIS.

While few references can be found relative to the local *x*-ray treatment of the lesions of dermatitis herpetiformis, several authors have advised such treatment H. Fox treated 4 cases with negative results. Fraser noted some improvement in the eruption of his case, following three unfiltered *x*-ray exposures of 75 r each, at weekly intervals Wise noted a very distinct improvement in the case of a child, aged five years, two weeks after starting Fowler's solution and small doses of unfiltered *x*-rays We tried roentgen therapy in 10 cases Itching was temporarily relieved in most of the cases, and in several patients the eruption was definitely improved. There was no permanent benefit.

Attention has been drawn to spinal roentgen therapy (paravertebral or radicular roentgen therapy, see Chapter XXX) in dermatitis herpetiformis. Maderna reports rapid alleviation of itching with disappearance of the eruption in 2 cases, following a single *x*-ray exposure to each sacrolumbar and interscapular field Krynski treated 2 cases successfully with spinal irradiation He does not believe this therapeutic procedure is actually curative

H. R. Foerster reports partial success in production of remissions, with reduction of pruritus, and definite improvement in the eruption In some cases one treatment sufficed, whereas in others two treatments were given at an interval of six weeks The rays were directed perpendicularly to the spinous processes at the level of the second dorsal vertebra and the second lumbar The dose was about 344 r filtered through 3 mm of aluminum. The factors were 5 ma, 112 kv, time, seven and a quarter minutes; distance, 10 inches Foerster, at a later date, warns that judgment of the efficacy of this form of therapy should not be based on single roentgen treatments or short periods of observation Beneficial effects have usually not been apparent until a number of treatments have been given Several of his cases have remained well for long periods, one for as long as eighteen months.

Schmidt treated successfully with spinal irradiation and a ketogenic diet a patient with dermatitis herpetiformis of five years' duration, who subsequently remained free from lesions for several months

Michelson obtained excellent subjective and objective improvement in a case of a number of years' duration, which had been recalcitrant to all other therapy. Two treatments of $\frac{1}{2}$ skin erythema dose, filtered through 3 mm of copper, were administered with an interval of two

months between treatments Goeckerman obtained definite remissions in 3 out of 5 cases, but they were not permanent Bejarano and Soto treated 13 cases by spinal irradiation Of these, 7 were definitely cured, 3 temporarily improved, and 3 failed to remain under observation They conclude that no method is comparable to spinal irradiation in the *treatment of dermatitis herpetiformis*

Since the advent of the sulfonamides *x*-rays have been seldom used for this disease We do not recommend irradiation

EPIDERMOLYSIS BULLOSA

Berger reports that the skin in a case of the hereditary type became more irritable as a *result of roentgenization* Lesions were *more* numerous after irradiation than before the treatment

Pels case, a child, aged seven and a half years, who had had the condition since birth, received moderate doses of roentgen therapy apparently without success Mitchell s case, a girl aged fifteen years with the congenital type, *had received innumerable x ray exposures* without benefit She was also resistant to other forms of therapy

In the case of epidermolysis bullosa acquisita successfully treated by Kittredge, the hand which received weekly (75 r) doses of unfiltered *x*-rays in addition to other treatment, responded more rapidly than did the unirradiated hand which served as a control

PEMPHIGUS

Weiss reports disappearance of vegetations under the influence of roentgenization in a case of pemphigus vegetans Scholtz obtained temporary improvement with *x*-rays in a case of pemphigus foliaceus We tried *x* rays and radium in one case of pemphigus foliaceus without benefit Gilchrist gave 70 weekly *x* ray treatments to a case of pemphigus of this type without benefit X rays were tried again at a later period with some benefit

Gilchrist caused lesions of the Senear Usher type to disappear following the application of a half strength radium plaque for five minutes to each patch

Maikowa-Kudrjawceva treated a case of pemphigus vegetans of the scalp and glabrous skin with *x* rays The patient was still free of lesions sixteen months after the last treatment The dosage was $\frac{1}{3}$ erythema dose filtered through 0 5 mm of aluminum administered in series of three treatments on successive days, at intervals of one month The scalp received five series, the dosage *for the last two being* $\frac{1}{2}$ erythema dose, without a permanent alopecia ensuing

These are old references It is now the consensus that *x*-rays are of little if any value for pemphigus

HERPES.

Pfahler reports a case of herpes simplex with almost continuous eruption for three years. After eight mild *x*-ray exposures the eruption disappeared and remained absent for nine months, when it again appeared.

Mitchell has seen a number of cases of localized, recurrent herpes simplex which have responded satisfactorily to *x*-rays applied to the affected area. He believes it lessens the severity of the attacks and increases considerably the interval between them. Stillians has had some success with this type of therapy. Goldsmith believes that recurrences at the same site can often be stopped by a few mild treatments.

Robert treated 19 cases of recurrent herpes with *x*-rays. Eight were cured, 8 improved and there were 3 failures. Zimmern and Chavany recommend *x*-ray treatment for both recurrent herpes simplex and for zoster.

Terry exposed the eye of a rabbit to a dose of *x*-rays as large as could be safely administered and found it insufficient to produce any effect on the virus of herpes simplex.

Newcomet, Schiff, Wickham and Degrais and others aver that small doses of radium and *x*-rays relieve the pain associated with herpes zoster. Wettenhall has found roentgen therapy efficacious against the eruption, chiefly during the early stages when the lesions are still acute. Schamberg found filtered *x*-rays of service in the treatment of the persistent pain in some cases of zoster. Marin speaks highly of small filtered doses of *x*-rays applied to the spine in controlling the neuralgic pains occasionally associated with herpes zoster (paravertebral therapy; see Chapter XXX). Stephenson also has noted a shortening of the course of the disease following treatment over the involved spinal nerve roots with the more penetrating rays.

Keichline reports the successful treatment of 62 cases of herpes zoster. The procedure followed was the administration of 148 r through 3 mm. of aluminum at 30 cm. distance to the eruption and corresponding root ganglion. Relief of pain and subsidence of the eruption followed. Ninety per cent of the patients (all early cases) required only one treatment, 8 per cent received a second treatment the following day, and 2 per cent of recurrent and postparalytic cases required three treatments given every ten days. Goldsmith does not feel that experience has substantiated the value of deep *x*-ray exposures over corresponding nerve roots in the treatment of postherpetic pain.

Our results with *x*-rays in cases of herpes simplex and zoster, both in relation to the eruption and pain, have been disappointing.

PITYRIASIS ROSEA.

Allen treated 3 cases of pityriasis rosea with *x*-rays. He thought that the eruption in each instance disappeared more rapidly than would

have been the case under regular dermatologic remedies. Blaschko reports the disappearance of an eruption of pityriasis rosea in a fortnight under the influence of *x*-rays.

In a case of pityriasis rosea in which the lesions had occurred in repeated crops over a period of four months, Jamieson found that some lesions disappeared after irradiation only to recur. King and Hamilton found that the eruption of pityriasis rosea disappeared more rapidly after *x*-rays (150 to 225 r) than after any other treatment. In some of their cases they irradiated one-half of the body and found that the eruption so treated cleared up on the average of two weeks sooner than the portion which did not receive *x*-ray treatment.

The histologic changes in pityriasis rosea are such that one would expect roentgen therapy to be beneficial. The disease, as a rule, is very mild, it is self-limited and it usually disappears in a few weeks. Occasionally the attack is severe and it may last for two or three months. In such instances roentgenization might be of value. As a rule, however, much quicker and better results are obtained with ultraviolet radiation, exfoliating lotions and ointments, and especially with injections of a fungus extract, as recommended by Vass.

PITYRIASIS RUBRA PILARIS

Pusey obtained improvement with large doses of *x*-rays in one case of pityriasis rubra pilaris of moderate severity. The late G. H. Fox noted that itching was arrested and that the infiltration was markedly lessened in one case treated with *x*-rays. H. Fox treated one case with disappointing results. Pernet reports a case in which three *x*-ray exposures were given to a limited area of the front of the chest without any apparent effect.

H. R. Foerster and Wieder obtained a definitely favorable effect in a case of pityriasis rubra pilaris by irradiating the region of the thymus gland according to the method introduced by Brocq in the treatment of psoriasis. A complete remission was not obtained, but frequent exacerbations usually subsided promptly to repetition of this treatment. A total of 20 treatments was given. Two other cases of pityriasis rubra pilaris have been treated similarly by these observers. There was a remarkably rapid disappearance of the eruption in one instance, the skin remaining clear for six months while the patient was under observation. In the other case the eruption remained unaltered. Everett Lain obtained considerable improvement in one case with two or three filtered *x*-ray treatments to the thymus at intervals of four weeks.

RAYNAUD'S DISEASE

Newcomet has found *x*-rays useful in this disease. The ulcers heal more quickly and pain is lessened.

Borak treated 11 cases of Raynaud's disease with spinal roentgen therapy (paravertebral therapy, see Chapter XXX) and obtained subjective and objective improvement in all except 1, which was really a case of scleroderma When the upper extremities were involved, the lower cervical and upper thoracic spine was irradiated, and when the lower extremities were affected, the lower thoracic and upper lumbar spine was treated The dosage administered was ⅓ erythema dose (200 r) filtered through 0.5 mm. of zinc. The skin distance was 30 cm., and the kv., 170. The focal dose amounted to 60 to 90 r This was given in a series of three treatments at four- to eight-day intervals. The entire treatment consisted of two or three such series. There was an interval of four to eight weeks between the series. Early cases responded better than those of long duration. Of 6 cases under observation for several years, 4 remained free of recurrences for from two to three and a half years.

Monier-Vinard, Delherm and Beau treated 7 cases of Raynaud's disease with improvement, using essentially the same technic. They believe it advantageous to give short series of radiotherapy of medium penetration They administered three sessions a week of 400 r each, filtered through 5 mm. of aluminum There was a rest period between series of at least three weeks

SCLERODERMA.

Several years ago there were a number of cases of scleroderma, to which *x*-rays had been applied, presented at the Manhattan Dermatological Society by Geyser, Oulmann, Weiss and others. In a few instances there was some improvement; in most of the cases the results were negative. Belot cured one case and definitely improved several other cases of circumscribed scleroderma with large monthly doses over a period of several months. Pfahler found that the results of roentgen therapy in scleroderma were slight when compared to the time and energy expended. MacKee observed fairly rapid healing of long-standing ulcers, apparently as a result of a few mild *x*-ray treatments in a case of widespread scleroderma of the legs There was no effect on the scleroderma Belot and Nahan report a patch of scleroderma of the foot cured with radium in three months

It is obvious that scleroderma is exceedingly refractory to local irradiation. Excessive dosage may convert normal skin into a condition resembling scleroderma. The end result of scleroderma is often atrophy or sclerosis, which, also, may follow long-continued irradiation. For these reasons it is advisable to employ considerable caution when using *x*-rays or radium locally in the treatment of scleroderma. It is our opinion that irradiation to the local skin lesions is not indicated in this disease, except, perhaps, in a few selected cases.

H. R. Foerster has noted regression in lesions of circumscribed scleroderma after irradiation of the cervico-thoracic and lumbo-sacral

regions of the spine (paravertebral therapy, see Chapter XXX). The dose generally administered is approximately 344 r of filtered radiation (3 mm aluminum). While Foerster has had the opportunity to observe his cases only for a short time, he considers the method worthy of further investigation, because of its simplicity and safety in contrast to the usual surgical procedure. The German medical literature also contains references to the successful treatment of cases with this form of therapy.

Bloch first recommended the use of thorium X ointment for the treatment of scleroderma. Epstein reports beneficial effects in nearly all of his cases treated in this manner. The best results were obtained in scleroderma circumscripta. He employs an ointment of 1000 to 2000 electrostatic units in 1 gram. The ointment is applied with a wooden stick to the affected area, covered with gutta-percha, bandaged and left in place for eighteen to forty-eight hours, usually twenty-four hours. The treatments are given at intervals of six to twelve weeks. As many as ten treatments have occasionally been applied to one area. No untoward late sequelæ have ever been observed during the fifteen years this therapeutic agent has been used at the Breslau Clinic. Strassburger has suggested the use of radon ointment for this condition. We have been unable to improve one single case of scleroderma with x-rays, grenz rays, radium or other radioactive substances.

Abramowitz and Sheer presented a baby at the September and November, 1926, meetings of the Brooklyn, N. Y., Dermatological Society, with sclerema neonatorum. The case has subsequently been reported in the literature by Sheer. The sclerema disappeared following three unfiltered x ray exposures of 100 r each, at intervals of three weeks. There was a substantial gain in weight and general health.

ACRODERMATITIS

Bodin has found x-rays of service in "continuous suppurative acrodermatitis," a pyodermic eruption of the hands and feet. A case treated by Mestre failed to respond to x-rays and other forms of therapy. Bordier reports a case of this disease successfully treated by radicular (paravertebral, see Chapter XXX) radiotherapy. Filtered x rays were applied to the sacral region. More recently he reports another case treated successfully, the patient remaining free from lesions for one year. A series of oblique irradiations to the cervical region was given on three consecutive days. The dose at each session was 330 r filtered through 6 mm. of aluminum.

Gross believes that most relief in acrodermatitis chronica atrophicans, particularly where there is pain, is to be obtained from medical diathermy, but he has also obtained gratifying results with irradiation of the lumbar spine. He points out that this type of therapy is necessarily symptomatic. Epstein also reports beneficial effects in acro-

dermatitis chronica atrophicans from the use of thorium X ointment (see under Scleroderma). This type of therapy seemed to have a much better effect on the inflammatory and infiltrative manifestations of this disease than filtered roentgen therapy, diathermy, and the other types of treatment which have been utilized in the past.

URTICARIA.

Lawrence claims the cure with *x*-rays in two weeks of a case of severe generalized urticaria of long standing. It is the duty of the physician to locate and remove the cause of urticaria This can be often accomplished In cases where it is impossible to cure the disease, and the patient is suffering severely from the itching, *x*-rays may possibly be of service, but much better results can be obtained with conventional modern therapy There has been no personal experience Lebon, Le Genissel, and Marie treated 4 cases of chronic urticaria with filtered irradiation over the spleen and obtained complete relief in 3 cases

URTICARIA PIGMENTOSA.

Torok and Schein report a complete and permanent cure of a case of urticaria pigmentosa by means of *x*-ray treatment The exposures were followed by erythema In a case treated by Jacob the patient was given three exposures at weekly intervals. There was no reaction The eruption did not disappear, but the lesions ceased to swell when irritated and there was no factitious urticaria Itching was absent and no new lesions developed The relief lasted for three months, at which time all the symptoms returned A second course of treatment again effected relief The outcome of the case is unknown

Michael treated 1 case of the adult type of urticaria pigmentosa with *x*-rays The eruption disappeared, but recurred in about a year He reports 3 similar cases in the literature H Fox had a somewhat similar experience with a case of the adult type The eruption disappeared following ten weekly (75 r) doses of *x*-rays at weekly intervals, only to recur six months later as profuse as before treatment.

In urticaria pigmentosa in infants associated with hyperplasia and persistence of the thymus gland, Hollander found that the application of heavily filtered radium applied to the region of the thymus resulted in involution of the eruption Andrews treated successfully a case of the localized, nodular type of urticaria pigmentosa with a suberythema dose of radium

LICHEN URTICATUS.

Lawrence reports good results in obstinate cases of lichen urticatus with small doses of *x*-rays.

TRACHOMA

Trachoma is an ophthalmologic disease but it is of some interest to the dermatologist Excellent results, even permanent cures may be had with both radium and *x*-rays In our experience beta rays of radium are more efficacious and they are more easily applied than are *x* rays The literature on this subject is rather voluminous Stephenson and Walsh, and Mayo observed good results with *x*-rays in 1903 Yasvutinski, Schamberg Pusey Newcomet and Krill

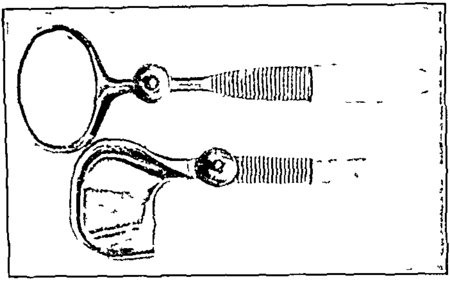

Fig 317 —Instrument for applying radium to the mucous surface of eyelid Protection for the eyeball is also accomplished (Dr W A Pusey)

Lipowitz and Salzmann, and many others have testified to the efficacy of *x*-rays in this disease Selenkowsky, Darier Pusey, and *others report* good results with radium Selenkowsky and Malischeff prefer radon for severe cases of granular trachoma They apply 0 3 to 0 6 mc per cc filtered through 1 to 2 mm of lead for two to three days Abbe obtained permanent cures in 10 cases of vernal catarrh with radium Our results have been satisfactory in the few cases treated both in vernal catarrh and trachoma In each instance the diagnosis was made by *an ophthalmologist Most of the* cases were diagnosed as vernal catarrh

Technic —The upper lid may be everted and a flat radium applicator placed in contact with the mucous membrane Radium can be applied to the lower lid by pulling the cheek downward with the fingers The artificial ectropion can be maintained by attaching one end of a strip of zinc plaster to the lower eyelid and the other end to the neck under the mandible Before fastening the lower end of the zinc plaster the cheek should be pulled downward and the neck upward Pusey holds the

everted lid in position with special lid forceps, which not only holds the lid in position but also protects the eye. For a half-strength applicator, covered with oiled silk, and held in contact with the mucosa, the dose will be about two minutes, once weekly. With a screen of 0 1 mm aluminum the weekly dose will be about five minutes. No protection is necessary for the eye

The preparation is the same for the application of x-rays A diaphragm made of lead foil should be used to protect all but the affected areas If the shield irritates the eye a drop of procaine solution will overcome the difficulty. Brass shields for the eyeball are on the market The dose is 75 r, once weekly, unfiltered

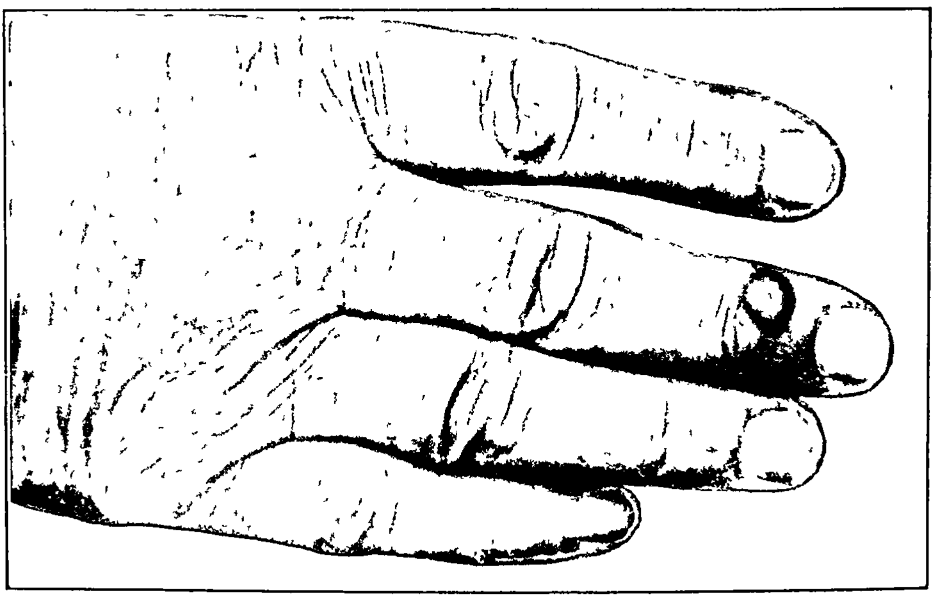

Fig 318 —Synovial lesion of the skin (Courtesy of Dr R L Sutton)

SYNOVIAL LESIONS OF THE SKIN.

Hyde and Ormsby cured several cases of synovial lesions of the skin with x-rays. Lingenfelter reports a cure in one case Sutton cured one patient with one application of unfiltered radium Ormsby's cases were treated fractionally, not more than 10 or 12 mild, unfiltered applications being required In Lingenfelter's case two fairly strong exposures at intervals of eleven days sufficed for a cure. The lesion had resisted solid carbon dioxide and other methods of treatment In Sutton's case the lesion disappeared as a result of 40 mg.-hr. of unscreened radium We have cured a number of such cases with one or two suberythema doses of x-rays, both filtered and unfiltered. We have also had several failures. Mitchell, employing filtered roentgen therapy, produced considerable improvement with great reduction in the quantity of fluid of a synovial lesion on the distal joint of the second toe which extended a considerable distance up the dorsum of

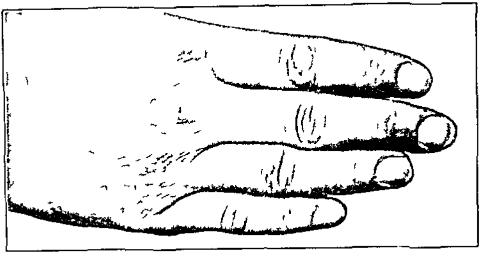

FIG 319 —Same patient as shown in Fig 318 after radium treatment (Courtesy of Dr R L Sutton)

FIG 320 —Synovial lesion of the skin before treatment

FIG 321 —Same as Fig 320 after one intensive unfiltered x-ray treatment

the foot. We recently treated a synovial lesion of the finger successfully with a single treatment consisting of 600 r of unfiltered *x*-rays.

Savatard concludes from a study of the literature and 3 cases of his own that these tumors, though clinically similar, may vary in origin He believes that the majority of them are not of synovial origin and suggests the name of "periarticular fibroma of the skin" as more appropriate. One of his cases was treated with radium and cured following a single application. He concludes that roentgenotherapy seems to be the ideal treatment.

ELEPHANTIASIS.

Sorel and Soret report the cure of one case of pseudo-elephantiasis (streptococcic) with *x*-rays. Snow also reports benefit in this type of elephantiasis. Variava irradiated 5 cases of elephantiasis of the legs, due presumably to filiaria, over a period of four months with encouraging clinical results. The period of observation was too short for the observer to care to draw any definite conclusions.

FORDYCE'S DISEASE.

Pinch cured one case and improved another case of Fordyce's disease with radium.

FORDYCE–FOX DISEASE.

Brown reports striking improvement in one case of "chronic itching papular eruption of the axilla" with *x*-ray treatment.

L. B. Robinson administered three unfiltered *x*-ray treatments of 75 r each in a case of this disease with some improvement in the itching and a decrease in the size of the papules. Kesten treated a case of Fordyce-Fox disease of five months' duration with occasional *x*-ray treatment over a period of four months. During this time no new lesions appeared, many of the old papules disappeared, and the itching decreased markedly. Peck had a patient in whom this condition had been present for eighteen months. A great deal of roentgen therapy had been applied without any effect on the course of the eruption.

Cipollaro believes that *x*-rays control the pruritus of Fordyce-Fox disease temporarily. H. Goodman states that in the 65 cases of Fordyce-Fox disease found in the literature, itching persisted despite the administration of sufficient radiation to cause a dermatitis.

Miskjian and Sullivan treated 3 cases of Fordyce-Fox disease with *x*-rays. Two of these were unimproved. The case which improved obtained considerable relief for a few months after three filtered *x*-ray treatments of 200 r each were administered at two-week intervals. Goldsmith considers roentgen therapy as an undoubtedly useful symptomatic remedy in this disease. We obtained moderate

improvement in a case of ten years duration. Five *x*-ray treatments of 75 r, unfiltered, were administered at weekly intervals.

LEPROSY

Sandidge and Neill aver that nasal nodules were cured and lepra bacilli disappeared from the nasal discharge after they placed radium tubes in the nose. MacKee treated several cases of leprosy with *x* rays years ago with indifferent success, which is in accord with references to be found in the literature. Mitchell treated a lesion suspected of being leprosy with four *x*-ray treatments of 150 r each without change. While the aggregate clinical impression and the histologic picture favored leprosy in this case, lepra bacilli were not found in the section or in repeated nasal smears. MacKee and Cipollaro treated a case of macular nodular and anesthetic leprosy with six unfiltered *x*-ray treatments of 75 r, at weekly intervals. There was slight, if any, involution of the lesions.

LICHEN NITIDUS

In a verbal communication, H. Fox tells of a case of lichen nitidus in which the lesions disappeared as a result of unfiltered fractional *x* ray treatment. We have treated two cases in which the eruption disappeared following the administration of six weekly treatments with unfiltered *x* rays, each treatment consisting of 75 r.

PURPURA HÆMORRHAGICA

Goldmark and Jacobs and many others claim good results in this disease by applying *x*-rays and radium to the spleen or to the pelvic organs. Pancoast, Pendergrass and Fitz-Hugh did not obtain very good results with comparatively small doses applied to the spleen. They give a complete bibliography.

Hippe and Kochmann treated 7 cases of thrombopenic purpura in children with irradiation of the spleen and concluded that this was the treatment of choice in cases of severe thrombopenic hemorrhage. Irradiation of the spleen regularly induced instantaneous and lasting hemostasis and a rapid increase in the number of thrombocytes to normal values. The effect lasted in some cases up to two months. They administered 110 to 180 r filtered through 0.5 mm. of copper and 1 mm. of aluminum to the spleen at a distance of 30 cm. No harmful effects were observed from this dosage. Constitutional thrombasthenia was found to be apparently more difficult to influence by irradiation than acute thrombopenic purpura.

Minot and Buckman believe that irradiation of the spleen in purpura hæmorrhagica may be beneficial when appropriately given, but probably rather often will be found ineffective. Fowler states that the use

of roentgen therapy in this condition has been found to be of only temporary value Rudisill, Jr., on the basis of his experience with this therapeutic agent, concludes that it is very valuable and is possibly a specific therapeutic agent in primary or uncomplicated thrombopenia with hemorrhage. His factors were: 4 ma.; 200 kv. The dose was 200 r filtered through 0 5 mm. of copper and 1 mm. of aluminum. Some cases received from one to six treatments.

Mettier, Stone and Purviance, from a study of 7 cases, conclude that roentgen therapy in doses of 200 to 300 r will produce an increase in blood platelets in patients with idiopathic thrombocytopenic purpura hæmorrhagica. A paper by Mettier and Purviance contains a summary of their work on this subject.

MOLLUSCUM CONTAGIOSUM.

Brown reports the cure of 1 case of long standing with fractional *x*-ray therapy. H. Fox treated 2 cases successfully with *x*-rays, the condition in both disappearing after seven or eight doses (75 r, unfiltered) given at weekly intervals One of these patients had as many as 150 lesions on the thigh.

SEBACEOUS CYST.

Occasionally a small sebaceous cyst will disappear following one or several suberythema doses of filtered *x*-rays at monthly intervals. As a rule such treatment fails.

HYDRADENITIS SUPPURATIVA

We have used *x*-rays successfully in cases of hydradenitis suppurativa when there have been no sinuses. In chronic cases in which individual lesions are connected by sinuses, *x*-rays have not been successful in our experience. The technic that we have used is one treatment weekly for from four to eight weeks. The filter is 3 mm. Al and the dose 135 r.

MILIUM.

We have treated several cases of milium with weekly doses of *x*-rays with disappointing results.

MUCOUS RETENTION CYST (SUTTON).

We have treated a number of these lesions with radium and *x*-rays, both filtered and unfiltered, with negative results. This was a surprise, because the treatment seems logical.

ADDITIONAL MISCELLANEOUS DISEASES.

We have treated 2 cases of folliculitis ulerythematosa reticulata with *x*-rays without substantial improvement. Several cases of monil-

ethrix were treated with x rays with negative results Roentgenization has been found useful in some cases of neurotic excoriations An apparently good result was obtained in one case of dermatolysis exfoliativa of the palms with a few fractional unfiltered x-ray exposures

BIBLIOGRAPHY

ABBE R Radium Efficiency in Non Malignant Surgical Conditions Med Rec 90 47 1916

ANDREWS G C in discussion on Wise Fred Urticaria Pigmentosa Neviformis (?) Arch Dermat and Syph 26 183 1932

BEJARANO J and SOTO J La Roentgenterapia in Dermatologia Actas dermo sif 26 785 1934

BELOT J Radiotherapy in Skin Diseases Translated from the 2d French ed by W Deane Butcher New York Rebman Company 1905 p 317

BELOT J and NAHAN L L électro-radiothérapie des sclerodermies Jour de radiol et d électrol 6 515 1922

BERGER F R M Ein Fall von Epidermolysis bullosa hereditaria und seine Reaktion auf Rontgenbestrahlung Arch f Dermat u Syph 80 23 1906

BLASCHKO A Zur Rontgenbehandlung der Hautkrankheiten Verhandl d Berl med Gesellsch (1908) 39 Pt 2 398 1909 Ref Arch Roentg Ray 14 129 1909

BODIN L Les acrodermatites suppuratives continues Paris méd 30 185 1920

BORAK J Behandlung der Raynaudschen Krankheit durch Ruckenmarksbestrahlungen Wien klin Wchnschr 40 800 1927

——— Die Rontgenbehandlung der Raynaud schen Krankheit Wien med Wchnschr 79 536 1929

BORDIER, H Effets de la radiothérapie médullaire dans deux affections rares Arch d électric méd 28 161 1920

——— Acrodermatite continue de forme suppurative Guérison par la radiothérapie médullaire Arch d électric méd 35 436 1927

BROWN M The Roentgen Ray Treatment of Various Dermatoses Arch Dermat and Syph 11 764 1925

CIPOLLARO A C Fox Fordyce s Disease Arch Dermat and Syph 33 907 1936

DARIER A Du mode d action du radium sur la conjonctivite granuleuse Rev de thérap méd chir 73 115 1906

EPSTEIN S Zur Behandlung von Sklerodermie und Acrodermatitis chronica atrophicans mit Thorium X (Degea) Arch f Dermat u Syph 167 533 1932 1933

FOERSTER H R Spinal Roentgen Ray Therapy in Dermatitis Herpetiformis Wisconsin Med Jour 29 571 1930

——— in discussion on Senear F E and Caro M R Dermatitis Herpetiformis Arch Dermat and Syph 24 702 1931

——— Roentgenotherapy of the Spinal Region in Dermatology Arch Dermat and Syph 25 256 1932

——— in discussion on Mayo Clinic Scleroderma with Sclerodactylia Arch Dermat and Syph 22 156 1930

FOERSTER H R and WIEDER Pityriasis Rubra Pilaris Arch Dermat and Syph 20 373 1929

FOWLER W M Thrombopenic Purpura an Analysis of 160 Cases Ann Int Med 9 1475 1935–1936

FOX G H Pityriasis Rubra Jour Cutan Dis 23 498 1905

FOX H The Coolidge Tube in the Treatment of Non Malignant Diseases of the Skin Jour Cutan Dis 35 599 1917

——— Standardized Roentgen Ray in the Treatment of Skin Diseases With Special Reference to Eczema New York Med Jour 112 837 1920

——— in discussion on Abramowitz Urticaria Pigmentosa (Adult Type) Arch Dermat and Syph 20 258 1929

——— in discussion on Bechet Paul Atypical Molluscum Contagiosum Arch Dermat and Syph 25 758 1932

FRASER J F Dermatitis Herpetiformis (Duhring) Arch Dermat and Syph 34 909 1936

GILCHRIST T C Case for Diagnosis (Pemphigus Foliaceus?) Jour Cutan Dis 34 377 1916

——— A Case for Diagnosis Arch Dermat and Syph 16 658 1927

GOLDMARK, C, and JACOBS, A W Purpura Hemorrhagica (Postpartum) Treated with Radium and Roentgen Ray with Report of a Case, Am Jour Obst and Gynec, **8**, 208, 1924

GOLDSMITH, W N Recent Advances in Dermatology, Philadelphia, P Blakiston's Son & Co, Inc, 1936, pp, 33, 374, 378, 491.

GOLUBININ, L Ein Fall von therapeutischer Anwendung der Rontgenstrahlen bei Morbus Addisonii, Therap d Gegenw, **46**, 203, 1905

GROSS, P Acrodermatitis Chronica Atrophicans, Arch Dermat and Syph, **28**, 291, 1933

HIPPE, H, and KOCHMANN, R Die Behandlung der thrombopenischen Purpura im Kindesalter mit Rontgenbestrahlungen der Milz, Jahrb f Kinderh, **136**, 302, 1932

HOLLANDER, L Urticaria Pigmentosa with Hyperplasia of the Thymus Gland, Arch Dermat and Syph, **11**, 611, 1925

JACOB, F H A Case of Urticaria Pigmentosa Treated by X-Rays, Brit Med Jour, **1**, 1301, 1907

JAMIESON Pityriasis Rosea Perstans, Arch Dermat and Syph, **19**, 335, 1929

KEICHLINE, J M Sixty-two Cases of Herpes Zoster Successfully Treated with X-Rays, Radiology, **22**, 372, 1934

KESTEN, B Fox-Fordyce Disease, Arch Dermat and Syph, **25**, 579, 1932

KITTREDGE, H E Epidermolysis Bullosa Acquisita Successful Treatment, Arch Dermat and Syph, **30**, 537, 1934

LAWRENCE, H X-Ray Baths, Trans 6th Internat Dermat Cong, New York (1907), **1**, 487, 1908, Abstr, Jour Cutan Dis, **26**, 247, 1908

LEBON, LE GENISSEL and MAIRE Quelques résultats obtenus par la radiothérapie splénique dans l'urticaire rebelle, Bull et mém Soc de radiol méd de France, **22**, 205, 1934

LINGENFELTER, G P A Case for Diagnosis, Jour Cutan Dis, **31**, 647, 1913

LIPOWITZ, N S, and SALZMANN, G G Rontgentherapie bei Trachom, Fortschr a d Geb d Rontgenstrahlen, **38**, 359, 1928

MACKEE, G M Leprosy, Arch Dermat and Syph, **32**, 961, 1935

MACKEE, G M, and ANDREWS, G C Synovial Lesions of the Skin, Arch Dermat and Syph, **4**, 162, 1921

MAIKOWA-KUDRJAWCEVA, W Zur Rontgentherapie des Pemphigus vegetans, Rontgenpraxis, **1**, 701, 1929

MADERNA, C La roentgenterapia del simpatico nella dermatite erpetiforme del Duhring, Riforma med, **44**, 459, 1928

MARIN, A Les Rayons X en dermatologie, Union méd du Canada, **56**, 91, 170, 1927

MESTRE, J J Acrodermatite Suppurative Continue (Hallopeau), Arch Dermat and Syph, **19**, 152, 1929

METTIER, S R, and PURVIANCE, K Classification and Treatment of the Hemorrhagic States, Value of Roentgen Irradiation of the Spleen in Essential Thrombocytopenic Purpura Hæmorrhagica, Jour Am Med Assn, **108**, 83, 1937.

METTIER, S R, STONE, R S, and PURVIANCE, K The Effect of Roentgen Irradiation on Platelet Production in Patients with Essential Thrombocytopenic Purpura Hæmorrhagica, Am Jour Med Sci, **191**, 794, 1936

MICHAEL, J C Urticaria Pigmentosa in Adults Treated by the Roentgen Ray, Arch Dermat and Syph, **9**, 746, 1924

MICHELSON, H E Dermatitis Herpetiformis, Arch Dermat and Syph, **22**, 531, 1930

MINOT, G R Purpura, in Cecil, R L Textbook of Medicine, 6th ed, Philadelphia, W B Saunders Company, 1943, p 977

MISKJIAN, H G, and SULLIVAN, M Fox-Fordyce's Disease, Arch Dermat and Syph **34**, 702, 1936

MITCHELL, J H A Synovial Lesion Extending to the Dorsum of the Foot, Arch Dermat and Syph, **18**, 977, 1928

——— Epidermolysis Bullosa Congenita, Arch Dermat and Syph, **27**, 169, 1933

MITCHELL, J H, and NOMLAND, R Pityriasis Rubra Pilaris, Arch Dermat and Syph, **30**, 284, 1934

MONIER-VINARD, R, DELHERM, L, and BEAU, H La radiothérapie dans la maladie de Raynaud, Bull et mém Soc de radiol méd de France, **17**, 69, 1929

NEWCOMET, W S The Influence of the Roentgen Ray upon Raynaud's Disease, Am Jour Roentgenol, **1**, 153, 1913-1914

——— Radium and Radiotherapy, Philadelphia, Lea & Febiger, 1914, p 276

NEWCOMET, W S, and KRALL, J P Trachoma Successfully Treated with the X-Ray, New York Med Jour, **81**, 255, 1905, Arch Roentg Ray, **9**, 297, 1904

ORMSBY O S Synovial Lesions of the Skin Jour Cutan Dis 31 943 1913
ORMSBY O S and MONTGOMERY H Diseases of the Skin 6th ed Philadelphia Lea & Febiger 1943 p 1208
PANCOAST H K, PENDERGRASS E P and FITZ-HUGH T The Present Status of the Roentgen Treatment of Purpura Hemorrhagica by Irradiation of the Spleen Am Jour Roentgenol 13 558 1925
PECK S M Fox Fordyce Disease Arch Dermat and Syph 30 317 1934
PELS I Epidermolysis Bullosa Arch Dermat and Syph 16 637 1927
PERNET G A Case of Pityriasis Rubra Pilaris (Devergie) Brit Jour Dermat 36 373 1924
PFAHLER G E Carcinoma and Tuberculosis Treated by the Roentgen Rays Jour Am Med Assn 41 1406 1903
———— Case of Recurrent Herpes Jour Cutan Dis 25 124 1907
PICCININO G Rendiconto statistico-critico degli ammalati trattati con la roentgen terapia nell anno 1926 Internat Radiotherapie 2 690 1926–1927
PINCH A E H A Report of the Work Carried out at the Radium Institute London from January 1 1915 to December 31 1916 Radium 9 81 1917
POPP L Ueber die Radiotherapie der Nebennieren im Zusammenhange mit einem durch Rontgenbehandlung bedeutend gebesserten Falle von Addisonkrankheit Rontgenpraxis 2 128 1930
PUSEY W A The Principles and Practice of Dermatology 4th ed New York D Appleton & Co 1924 p 474
———— Treatment of Vernal Conjunctivitis with Radium Jour Am Med Assn 71 806 1918
RATERA J A Case of Addison s Disease Treated with X ray Rev clin de Madrid 14 357 1915 Abstr Jour Cutan Dis 34 414 1916
RIEDER H Die Rontgentherapie in der inneren Medizin mit Ausnahme der Neubildungen Lehrb d Rontgenkunde 3 413 1928
ROBERT P À propos du traitement de l Herpes Récidivant par la Radiothérapie Dermatologica 82 108 1940
ROBINSON L B Fox Fordyce Disease Arch Dermat and Syph 22 1146 1930
RUDISILL H JR Successful Treatment of Essential Thrombopenia with Hemorrhage by Roentgen Rays Jour Am Med Assn 107 2119 1936
SAVATARD L Peri articular Fibroma of the Skin (Synovial Lesion of the Skin) Arch Dermat and Syph 9 441 1924
SCHAMBERG J F in discussion on Newcomet W S Trachoma Treated with the X Ray New York Med Jour 81 255 1905
———— The Influence of X Ray in the Diseases of the Skin Am Jour Electro and Radiol 38 239 1920
SCHIFF E Radiumtherapie der Hautkrankheiten in Handbuch der Radium—Biologie und Therapie herausgegeben von Dr Paul Lazarus Wiesbaden Bergmann 1913 p 391
SCHOLTZ W Ueber den Einfluss der Rontgenstrahlen auf die Haut in gesundem und krankem Zustande Arch f Dermat u Syph 59 87 241 421 1902
SELENKOWSKY J W Becquerel s Rays (Radium) in the Treatment of Diseases of the Eye Treatment of Trachoma Granular Period Russk Vrach 5 189 224 264 1906
SELENKOWSKY J W and MALISCHEFF A A Ueber die Trachombehandlung durch Radiumemanation (Radon) Klin Monat bl f Augenh 82 162 1929
SKEER J Scleroma Neonatorum Report of Cure by X ray Therapy Arch Dermat and Syph 19 732 1929
SNOW W B in discussion on Brinkman M W Selective Harmonic Electric Vibration Jour Advanced Therap 21 718 1903
SOREL R and SORET A Note sur un cas d éléphantiasis avec troubles nerveux gueri après applications de rayons X Normandie med 13 97 1898
STEPHENSON F B Remarks on X Ray Treatment of Superficial Infections Am Jour Ophth 11 534 1928
STILLIANS A W Herpes Simplex of Buttock Arch Dermat and Syph 17 892 1928
SUTTON R L Diseases of the Skin 8th ed St Louis The C V Mosby Company 1931 p 533
TERRY T L X Rays Ineffective Against Herpes Virus Am Jour Ophth 11 534 1928
TOROK L and SCHEIN M Die Radiotherapie und Actinotherapie der Hautkrankheiten Wien med Wchnschr 52 847 899 1012 1064 1123 1902

VARIAVA, D H Elephantiasis traités par la polyradiothérapie, Ann Inst d'actinol, **9**, 28, 1935

VASS, I Treatment of Pityriasis Rosea with Trichophyton Extract, Arch Dermat and Syph, **51**, 203, 1945

VASYUTINSKI, A G Roentgen therapy for Trachoma, Russk Vrach, **4**, 12, 1905

WEISS, L Pemphigus Vegetans Improved by Four Exposures to the *X*-Ray, Jour Cutan Dis, **31**, 509, 1913

WICKHAM, L, and DEGRAIS, P Radiumtherapy, Translated by S Ernest Doré, London, Cassell, 1910, p 245

WISE, F Dermatitis Herpetiformis in a Child, Arch Dermat and Syph, **17**, 270, 1928

ZIMMERN, A, and CHAVANY, J A in Pohle, E A, Clinical Roentgen Therapy, (Philadelphia,) Lea & Febiger, p 517, 1938

CHAPTER XII

THE MEDICOLEGAL ASPECTS OF ROENTGEN AND RADIUM THERAPY *

The purpose of this chapter is to show the connection between the law and the practice of medicine in some particular matters The principles outlined and illustrations used are to show what we believe to be the general legal opinion in the United States with some variations in the same With our system of State and Federal courts a contrary opinion or different theory may be the law where the reader resides, for the law in one State or jurisdiction does not necessarily control or agree with that of another In some instances no opinion, general or otherwise has been found, or the principle is very unsettled, in such cases we have stated our own opinion

LEGAL REGULATION OF MEDICAL PRACTICE

Public policy requires regulation of the practice of medicine as it does of the law, to prevent those unable or unwilling to attain a certain degree of skill from practice and to keep those admitted up to the standard of the times Any who attempt to practice without license and authority are usually guilty of a crime and those who are authorized assume certain legal obligations toward their patients and the community In other words, a physician is liable in damages for a breach of these obligations and in extreme cases even liable to imprisonment New York provides by statute that any person who uses any designation tending to imply or designate him as a practitioner of medicine or who offers to or does practice medicine who has not received a license or authority from the State permitting him to do so, is guilty of a misdemeanor

Malpractice —Malpractice may be defined as wilful, ignorant, negligent acts or omissions, unskilful treatment or acts prohibited by statute, by a physician or surgeon, resulting in injuries to or death of the patient

Criminal negligence usually means such negligence as would be inferred from actions which are reckless or indifferent to results

Medical Practitioners —"A physician is one lawfully engaged in the practice of medicine It includes all who practice physic or surgery and is not limited to any one school of practitioners ' 48 C J 1063

"A surgeon may be said to be a physician who treats injuries deformities disorders, by manual operations and the use of surgical

* The late Mr Harold Bouton prepared this chapter in previous editions All of his material with slight changes has been used in this edition

instruments and appliances" 48 C J. 1065. It would also include treatment of disfigurements.

The New York statute defines the practice of medicine as follows. "A person practises medicine within the meaning of this article, except as hereinafter stated, who holds himself out as being able to diagnose, treat, operate or prescribe for any human disease, pain, injury, deformity, or physical condition, and who shall either offer or undertake by any means or methods, to diagnose, treat, operate or prescribe for any human disease, pain, injury, deformity or physical condition" It is said in 219 N. Y. 98, "the New York statute regulating medical practice applies to every means and method that could . . be used or claimed to be used to relieve or cure disease and infirmity unless excepted by the statute" Referred to and approved in 260 N Y. 383.

An *x*-ray operator, therefore, who offers or undertakes the application of *x*-rays or radium to any human being, either for diagnostic or curative purposes is practicing medicine, and he must be licensed.

"Superfluous hair on the face is a 'deformity' within the meaning of the New York State Public Health Law, and one who, not being a licensed and registered physician, holds herself out as being able to treat successfully such a deformity and undertakes to treat it with an electric needle, violates the statute regulating the practice of medicine and under the statute she (or he) is guilty of a misdemeanor and cannot recover for services rendered in giving such treatments" 102 N Y Misc 97 This case was overruled in 184 Ap Div 953 (N. Y) on the ground "that the evidence did not warrant the lower court deciding that the treatment administered constituted the practice of medicine" There was a dispute as to whether the operator had "held herself out" as set forth in the New York statute. Certainly a regularly licensed physician and surgeon or one associated with him "holds out" as such

"Liability under a statute prohibiting the practice of medicine without a license is not affected by the fact that the acts were performed and the medicines were administered as an assistant to or under the direction and supervision of a licensed physician and surgeon." 48 C J. 1079

RELATION BETWEEN PHYSICIAN AND PATIENT.

In the contract between physician and patient there are always necessary in order for it to be binding the essentials of. legality of object, a mutual understanding, mutual agreement and mutual obligation as to the subject matter, parties competent to contract, and a valuable consideration, which consideration need not be money So one cannot safely deal directly but only with an authorized representative of persons under twenty-one years of age, of unsound mind, or otherwise disabled. 48 C J 1131.

The physician is obliged to use a certain degree of care and skill but the patient must follow his physician's directions 48 C J 1134

Requisite Skill and Care —"In the absence of a special contract to do so, a physician or surgeon is not required to exercise extraordinary skill and care or the highest degree of skill and care possible nor, if not a specialist, the skill and care of the specialist or expert but is only required to possess and exercise the degree of skill and learning ordinarily possessed and exercised, under similar circumstances, by the members of his profession in good standing in that general locality, and to use ordinary and reasonable care and diligence, and his best judgment, in the application of his skill to the case" 48 C J 1113 "In determining the degree of learning and skill required, regard must be had to the state of medical or surgical science at the time' 48 C J 1116 It is said in 155 N Y 201, he is "bound to keep abreast of the times" 'The general rules requiring the exercise of ordinary and reasonable skill, care and diligence by physicians and surgeons, subject to qualification as to locality have been held to apply to, or have been stated with reference to, physicians and other persons operating *x* ray apparatus or applying radium" 48 C J 1121

'A 'specialist' has been defined as a physician or surgeon who applies himself to the study and practice of some particular branch of his profession A physician holding himself out as having special knowledge and skill in the treatment of a particular organ, disease, or type of injury is bound to bring to the discharge of his duty to a patient employing him as such specialist not merely the average degree of skill possessed by general practitioners, but that special degree of skill and knowledge possessed by physicians who devote special study and *attention to the treatment of such organ, disease, or injury, regard* being had to the state of scientific knowledge at the time" 48 C J 1116

This standard of skill and action continues throughout the relation of physician and patient and is required as well in the examination, diagnosis, selection of and application of treatment, as the following will show

"It is the duty of a physician to act with the utmost good faith toward his patient and if he knows that he cannot accomplish a cure or that the treatment adopted will probably be of no benefit, it is his duty to advise his patient of these facts and if he fails to do so he is guilty of a breach of duty" 48 C J 1133 cites 62 Minn 146, which said in substance 'Where a physician in charge of a sanitarium represents to an invalid, without knowing the truth or falsity of the representation that if the latter will take treatment at the sanitarium he can be cured and the invalid relies thereon, and enters the sanitarium but is not cured the physician is liable in an action for deceit" The principle of this case was approved in 148 Minn 325

"A wrong diagnosis of a case resulting from a want of requisite skill or care on the part of a physician and followed by detriment or injury

to the patient, renders the physician liable in damages. The fact that information and not medical treatment was sought does not excuse negligence in making the diagnosis." 48 C. J. 1126. "A general practitioner will not be held liable for making a wrong diagnosis of a very rare disease which can only be detected by a skilled expert." In this case glaucoma was the disease, 48 C. J. 1126. A physician entitled to practice his profession and possessing the requisite qualifications and applying his skill and judgment with due care is not ordinarily liable for damages consequent upon an honest error or a mistake of judgment in making a diagnosis, in prescribing treatment, or in determining upon an operation, where there is reasonable doubt as to the nature of the physical condition involved, or as to what should have been done in accordance with recognized authority and good practice. 48 C J. 1127. "A physician may have exercised a proper degree of skill and care in his treatment of a case, still if he fails to give the patient or his family or his attendants all necessary and proper instructions as to the care and attention best calculated to effect a cure he is guilty of negligence for which he may be held liable for resulting injuries." 48 C. J. 1131. "The welfare of the citizens of a State and therefore of a State itself, demands that those persons practicing medicine and surgery shall be able and careful. So in the absence of a statute the common law holds every physician or surgeon answerable for an injury to his patient resulting from want of the requisite knowledge and skill, or the omission to use reasonable care and diligence or the failure to exercise his best judgment This rule is elementary and has its foundation in most persuasive considerations of public policy. Its purpose is to protect the health and lives of the public, particularly of the weak or credulous, wary or unwary, from the unskilfulness or negligence of medical practitioners, by holding them liable to respond in damages for the result of their unskilfulness or negligence." 21 R C. L 379–380. "The rules governing the duty and liability of physicians and surgeons in the performance of professional services are applicable to manipulators of x-ray machines." 21 R C. L. 386 "The general rules requiring the exercise of ordinary and reasonable skill, care, and diligence by physicians and surgeons, subject to qualification as to locality, have been held to apply to, or have been stated with reference to, physicians and other persons operating x-ray apparatus, or applying radium

A judge in the New York County Supreme Court in 1918, in an action to recover from a roentgenologist and dermatologist of high standing for injury alleged to have been inflicted by alleged negligence in applying roentgen rays in the treatment of superfluous hair, charged the jury in effect "that a physician is not held to use unusual care, diligence and skill but only the average skill that is commensurate with the general standard of the profession in similar localities at the time of the acts alleged" However, the court added· "That in the case of a specialist the standard would be that ordinarily possessed by

practitioners devoting special attention and study to the same branch in similar localities, having regard to the present state of medical science "

In this same action the judge instructed the jury "not to take the opinions of the expert witnesses necessarily as conclusive evidence, *but merely as an aid to arrive at conclusions of fact* That it was necessary that the plaintiff showed by a preponderance of evidence that the defendant had been negligent and unskilful in his selection and administration of treatment or the plaintiff could not recover That a physician was not an insurer of good results and that if ill-results followed treatment he would be held to respond in damages only in case he had been negligent and unskilful in the selection of the *form of treatment and in its administration* "

The case of 67 Ohio St 106 substantially says "A surgeon employed to treat a case professionally is under an obligation to exercise the ordinary care and skill of his profession, in the light of modern advancement and learning on the subject, and that he will indemnify the patient against any injurious consequences resulting from his want of ordinary skill, care and diligence in the exercise of his employment That for the operation and subsequent necessary treatment he will use due care and diligence to the end that a recovery may be had This obligation exists as long as the relation of patient and physician and surgeon continues No promise to effect a cure is implied but due diligence, care and ordinary skill are implied undertakings It is the duty of the surgeon to exercise due diligence care and ordinary skill, not only in performing an operation, but also in the subsequent necessary treatment following such operation, unless the terms of employment otherwise limit the service or the patient gives the surgeon notice, that he will not or cannot afford the subsequent treatment " Cited and approved in 33 O Ap 166

The doctrine announced in this last case is very plain and practical so that both surgeon and patient will have their respective interests abundantly safeguarded The doctrine is promotive of the exercise of reasonable skill, care and treatment by the surgeon, not only at the specific time of the operation but also during the subsequent period of treatment necessary to a reasonable and substantial recovery The patient relies almost wholly on the judgment of the surgeon, and under the usual circumstances of each case is bound so to do, and if the injury is not reduced and a normal condition restored, as fully or as speedily as expected, the patient is still at liberty to rely on the professional skill care and treatment to complete such recovery so long *as the surgeon continues his employment with reference to the injury* Physicians and surgeons exercising reasonable care and skill need have no fear of it Reckless and careless physicians and surgeons should be kept in fear of this doctrine

The law should not impose on the patient a duty that he can know only through expert knowledge which he does not possess but as to

which he is compelled to accept the judgment of his physician or surgeon. The surgeon should have all reasonable time and opportunity to correct the evils which made the operation or treatment necessary, and even reasonable time and opportunity to correct the unavoidable mistakes incident even to skilled surgery. The doctrine announced here is conducive to that mutual confidence that is highly essential in the relation between surgeon and patient.

In Cal. 174 Pac. Rep. 654, the Supreme Court says: "The law on the subject of care and skill required of physicians in the treatment of patients is well settled;" quoting from 155 New York 209, "A physician and surgeon by taking charge of a case, impliedly represents that he possesses, and the law places upon him the duty of possessing, that reasonable degree of learning and skill that is ordinarily possessed by physicians and surgeons in the locality where he practices, and which is ordinarily regarded by those conversant with the employment as necessary to qualify him to engage in the business of practicing medicine and surgery. Upon consenting to treat a patient, it becomes his duty to use reasonable care and diligence in the exercise of his skill and the application of his learning to accomplish the purpose for which he was employed. He is under the further obligation to use his best judgment in exercising his skill and applying his knowledge." Further quoting from 187 Mich. 330; 153 N W. Rep. 695: "The difficulties and uncertainties in the practice of medicine and surgery are such that no practitioner can be required to guarantee results, and all the law demands is that he bring and apply to the case in hand that degree of skill, care, knowledge and attention ordinarily posessed and exercised by practitioners of the medical profession under like circumstances." It further quotes from 27 N. H. 474; 59 Amer. Dec 388: "It is never enough to show that he has not treated his patient in that mode, nor used those measures, which in the opinion of others, even medical men, the case required, because such evidence tends to prove errors of judgment, for which the defendant is not responsible, as much as the want of reasonable care and skill, for which he may be responsible." The Cal. case is cited and approved in Cal. 47 Pac Rep. 2nd, 797. The rule is said in a New Jersey case, 12 N. J. L. J. 269, to be: "The law requires of a physician that degree of knowledge and skill which is usual in the grade of the profession which he occupies, and in which he was employed in the particular case." This last case is cited and approved in the later case of 100 N. J. L 267, 126 At. 680, which also quotes and approves an earlier case, 49 N. J. L. 685, as follows: "The physician undertakes in the practice of his profession that he is possessed of that degree of knowledge and skill therein which usually pertains to the other members of his profession. The physician in attending his patients engages that he will use due care to discover the nature of the disease which gives occasion for his services, and in applying the usual remedies. But beyond this measure of skill and diligence the law makes no exaction. If he is to be held for results,

or as a guarantor of success, it can be only in virtue of his express engagement

In the case of 101 S E Rep 99, 178 N C 589, a consulting physician, failing to make a clinical diagnosis, based his diagnosis on a positive Wassermann reaction The plaintiff patient brought forward evidence to show that the diagnosis was erroneous, but failed to prove negligence In affirming a judgment of nonsuit the Supreme Court says that, 'the law governing the liability of a physician to his patient is well settled While there is an implied contract that the physician or surgeon who undertakes to treat a patient will use all known and reasonable means to accomplish the object for which he is called to treat the patient, and that he will attend to the patient carefully and diligently, there is no guaranty that he will cure him, or that he will not commit an error of judgment The law implies only that he not only possesses, but that he will employ in the treatment of the case, such reasonable skill, care and diligence as are ordinarily exercised in this profession But a physician or surgeon possessing the requisite qualifications and applying his skill and judgment with ordinary care and diligence to the diagnosis and treatment of a patient is not liable for an honest mistake or error of judgment in making a diagnosis or prescribing the mode of treatment, where there is ground for reasonable doubt as to the practice to be pursued' In this latter case the patient had been sent by his family physician for treatment to the defendant's hospital These principles held established in 201 N C 45

"It is well settled that the degree of learning and skill which a physician or surgeon is required to possess and exercise is that degree of skill and learning ordinarily possessed and exercised by members of his profession in the same line of practice in that locality The evidence in the record justifies the finding that the use of *x* rays in the diagnosis and treatment of human ills is recognized and practiced by the medical profession Such being the case we see no reason why a different rule should apply to practitioners in this line than is applied to other practitioners 35 App Cases Dist Col 57 To the same effect is 62 Fed 2nd 866

In roentgenologic work the required standards of technic change from year to year In each action it is for the jury to weigh the evidence given by the expert witnesses on both sides, and to determine if the defendant possessed and used proper skill The burden of proof is on the plaintiff, but the defendant to be successful must meet this proof with evidence sustaining his own contentions

The necessity of having accurate data and a well prepared case is shown in Va 96 S E Rep 360 *Jour Am Med Assn 72* 1100, 1919 where the Supreme Court of Appeals in a lengthy opinion affirms a judgment in favor of the plaintiff for damages alleged to have been occasioned to him by the alleged malpractice of the defendant physician in the treatment with *x* rays of eczema with which the legs and ankles of the plaintiff were affected The court says "it should

be borne in mind that the case involved two standards of professional skill and care by which the evidence as to the competency and the conduct of the defendant was to be measured. One standard has reference to the technic or mechanical operation of the *x*-ray apparatus and the other standard has reference to the possession and use of the professional skill and care incumbent on the defendant with respect to the diagnosis and treatment of the disease of the plaintiff in matters other than the mere mechanical operation of the apparatus. The two standards mentioned both involved, in this case, the highly specialized art of the treatment of the disease of the plaintiff by *x*-rays; and so far as they did so, expert testimony before the jury fixing such standards was essential to the support of the verdict of the jury, since otherwise the jury, to the extent of the questions involving such specialized art would have no standard in mind by which to measure the other facts proved in the case. Now, as to the mechanical standard of skill and care there was no expert evidence in the case except the testimony of the defendant and of other expert witnesses for the defendant; but there was sufficient evidence in the case, when measured by the mechanical standard fixed by the testimony of the defendant, to support the verdict of the jury. . . . It is deemed sufficient to mention only the following details of such evidence: There was evidence in the case to the effect that the defendant did not keep an accurate record of the *x*-ray treatment or any record of the exact dose of *x*-rays applied in the several treatments therewith; that if the standard dose only had been applied, it was extremely improbable that any bad results would have been caused. . . . The cross-examination of the defendant tended to show that his memory of the dose applied by him in the several treatments was not to be relied on. There were inconsistent statements made by the defendant at different times as to his opinion of the causes of the bad result; and there was other evidence to support a conclusion of the jury that the dose in fact applied was not in accordance with the mechanical standard fixed by the expert testimony of the defendant himself. It is true that such testimony did not show that the bad result might not have happened without fault of the defendant, but there was sufficient of such evidence, the credibility and weight of which was for the jury, tending to show that the bad result was more probably due to negligence or lack of skill on the part of the defendant as charged. This degree of proof is all that is required of a plaintiff in a civil case. He is not required to exclude by his proof the possibility of the result complained of having been due to causes for which the defendant is not responsible. . . . The cause of the injury being the *x*-rays was, however, but one element of fact in the case. As the jury was properly instructed, if the defendant exercised ordinary care and skill in the premises, the plaintiff was not entitled to recover damages, although the injuries complained of were caused by the *x*-ray treatment; and the question still remained whether the defendant did or did not exercise such care

and skill The court thinks there was sufficient evidence in the case, when measured by the general professional standard as well as by the mechanical standard of skill and care, to support the verdict of the jury It is correct to say that the standard which made it the duty of the defendant to make preliminary tests and examinations before subjecting the patient to *x*-ray treatment had to be tested by ascertaining if other like specialists in good standing, in the same or similar localities as the defendant, would have been guilty of the omission to make such preliminary tests and examination, which test had to be applied by measuring the evidence, as it might be introduced in the trial by the standard fixed by the testimony of experts on the subject, since the standard mentioned involved a highly specialized art of treatment Failure to warn of danger in the treatment was not *per se* negligence" In this case the verdict was for the plaintiff *The general principles of this case approved in 154 Va 381 where the* court on appeal found for the defendant because it held there was an absence of affirmative proof of defendant's negligence

The law holds that one of the fundamental requisites of the medical practitioner who uses the roentgen rays is the ability to make properly a skilful and careful diagnosis of the trouble of a patient and if the practitioner errs in that diagnosis through lack of proper skill or care, he must answer to the patient for the injury caused by the erroneous diagnosis just the same as he must answer for the application of improper treatment If by the exercise of proper care and skill a practitioner ought to find out that a person is unusually susceptible to injury by the roentgen rays and fails to do so, or after making the discovery fails to warn the patient of the danger, the practitioner is liable if he causes the patient injury which otherwise would not have happened And it would be unwise and unsafe to follow the diagnosis of any other medical practitioner unless one s own careful and skilful diagnosis led to the same opinion or if it differed without a consultation with the other, especially if the patient had been sent by him although the following case seems to hold to the contrary

The question of idiosyncrasy is likely to be one of diagnosis In the case of 35 Appeal Cases Dist Col 57 the plaintiff asked the court to instruct the jury to the effect that 'if the evidence shows that there is possibility that the patient might have been injured by the *x* rays due to some idiosyncrasy which would make her more susceptible to the influence of the *x*-rays regardless of the skill and care used, but which possibility or predisposition the physician knew or should have known then it was the duty of the defendant to so inform the plaintiff ' The Court of Appeals said 'There is nothing in the record to justify the inference that the condition of the plaintiff when the defendant subjected her to the *x* ray exposures was such as to render her peculiarly liable to injury Having been under a surgeon of recognized ability, and having been sent to the defendant by such surgeon for the purpose named we think the defendant, in the absence of anything

warranting a contrary conclusion, was justified in relying upon the judgment of the surgeon "

In 123 Va 113, 96 S. E. Rep 360 Sup. Court of Appeals heretofore quoted, the plaintiff claimed that "some people are more susceptible to the influence of the *x*-rays than are other persons and it was the duty of the defendant to make tests and examinations to determine the susceptibility of the plaintiff and to warn him of his susceptibility." The court says "there was no evidence tending to show that the plaintiff was more susceptible to injury by the *x*-rays than others Some experts testify that a person of fair complexion is more susceptible However, the plaintiff is of dark complexion, hence the fifth count cannot be supported "

"It is the duty of a patient to cooperate with his physician and conform to the necessary prescriptions and treatment, and follow all reasonable and proper instructions given." 48 C. J 1134

Acknowledged Want of Skill.—It is said in 48 C. J. 1133, citing as in point 88 Hun N Y 200, that "if a practitioner frankly informs a patient of his want of skill, or the patient is in some other way fully aware of it, the latter cannot complain of the lack of that which he knew did not exist " In the case cited the family physician on being called in to examine the patient announced that the wound was of a serious nature and character and that he did not regard himself as sufficiently experienced in surgery to treat the case properly He advised the family of the patient, who was about seventeen years old, to call in the services of a more experienced and skilful surgeon This was done and the two physicians together treated the patient for about a week, when another doctor was called in The first two physicians were sued for damages for malpractice and a verdict was given against them although the jury was charged by the trial court in the language quoted above, and the verdict was sustained on appeal The appellate court recognized the above rule but stated that the jury having been so instructed and having found for plaintiff it must be assumed that it found the facts and circumstances did not warrant the application of the rule

Release of Liability.—From either the view of releasing the physician or surgeon from liability on account of negligence, or of the assumption of risk by patient, while we have been unable to find a medical case in point, it is safe to say that there can be no legally binding agreement of a patient not to hold a medical practitioner liable for negligence, that is, before the services are rendered and the negligence occurs

Most, if not all, states by statute require a license to practice medicine and the common law requires an up-to-date standard of learning, skill and diligence These requirements establish an inherent public policy that would invalidate any attempt to rely on such an agreement. We believe that the weight of opinion in most if not all jurisdictions would hold such contracts void. If such a contract were legal it

would place a very dangerous weapon in the hands of unscrupulous persons and open the doors to the criminally inclined

"In the proper exercise of the police power of a state the legislature thereof may control and reasonably regulate the practice of medicine and surgery without violating constitutional provisions" 48 C J 1068 At the present time there are statutes in practically all states which provide that before a person may practice medicine and surgery in the state he must apply for and receive a license or certificate of qualification" 48 C J 1071 "The purpose of such statutes is to prevent persons who are not qualified from practicing medicine on the citizens of the state, and to protect the general public from injury which unskilled and unlearned practitioners may cause" 48 C J 1071, citing 211 Ill A 82 and 242 N Y 176, 151 N E 197

"The contract is quasi public," 67 Ohio St, at page 124, citing 64 Me 305

"The attempt to contravene the policy of a public statute is illegal Nor is it necessary to render it so that the statute should contain an express prohibition of such attempt It always contains an implied *prohibition, and to such attempt the principles of the common law are* invariably and deadly hostile, not always by an interference between the parties themselves, or by enabling the one to recall from the other where in *pari delicto,* what may have been obtained, but by at all times refusing the aid of the law to carry into effect or enforce any contract which may be the result of such intended contravention 1 N J M 394, citing Sharp v Teese, 9 N J Law 352

"A contract for exemption from liability for negligence is illegal if one of the parties is charged with duty of public service" 282 N Y S 280–150 N Y Misc 562 It was held in a railroad case in 24 N Y 196, 'The principle therefore is that parties cannot contract that they themselves may with impunity be guilty of wilful misconduct or of that degree of recklessness which is its equivalent' Where parties by a contract *enter into a relation carrying a legal duty, they cannot* stipulate for protection against negligence in performance" 211 Ala 525–101 So 177 "In the absence of legislative sanction contracts between parties for the purpose of relieving one or the other wholly or in part, from the legal consequences of future tortious or illegal conduct, are contrary to public policy and void" 206 Ill App 17–120 N E 259 A person cannot contract for exemption from consequences of his own negligence Kenney v Wong Le 81 N H 427 128 At 343

After there is an injury or claim of such the civil remedy for damages may be waived or released or settled without suit but if gross to the degree of criminal negligence the crime cannot be waived Each legal jurisdiction has particular practices prohibited and each must therefore be studied in a specific case

Express or Implied Understanding — There should be a complete and definite understanding and agreement as to the purpose of the contract

by both the patient and the physician. It is not usually practicable for the agreement to be reduced to writing and signed by the parties, but it would save much litigation and protect many defendants if it were. Avoid leaving it to implication by either party.

In the absence of such writing the agreement should be as definite as possible and the careful and wise practitioner will keep exact dated notes and photographic records, when possible, of conditions of the patient before, during and after his examination, diagnosis and treatment.

It should be made plain to the patient that the physician will do as well as he can with the condition presented, but that there is no certainty of result one way or the other, for the law does not call upon him to insure results, unless he has expressly undertaken and assured that results will be successful or satisfactory Such express assurances should always be definite and in writing or otherwise serious litigation is likely to result from misunderstanding between the parties.

In any event it is unwise to confine the arrangement to one specific treatment or method to be used, for a contract once made may not be modified by one party without the complete knowledge and consent of the other. In this type of contract, latitude and discretion should be reserved by the practitioner to enable him to use different or improved methods if the circumstances warrant At the same time the patient should be held to the strictest observance of directions, and a record kept of any departures

Consent to Treatment.—Although it may not be practicable in emergencies before undertaking the diagnosis or treatment of a person under twenty-one years of age, or a person suffering from temporary or permanent insanity or otherwise disabled, the consent of the person legally representing the patient should be procured if possible. Some cases hold consent of spouse is necessary. 48 C. J. 1131 An interesting case showing how claims arise against and must be defended by physicians is that of 83 N. J. L. 20. Here the plaintiff applied to the defendant physician to operate upon a rupture in his left groin that had been unsuccessfully operated on two years before On learning that the plaintiff was a poor man, the doctor engaged to operate free of charge. At the time fixed for the operation the plaintiff was placed under the anesthetic by two assisting surgeons who, when the operating surgeon came into the operating room, directed his attention to a rupture they had just discovered in the patient's right groin and which upon employment of the usual diagnostic tests was determined to be a serious menace to the patient and likely to cause his death should strangulation occur The surgeon thereupon operated upon the more serious rupture intending to operate also upon the other which he was prevented from doing by the patient's condition under the anesthetic The patient upon being informed that the operation would be completed on the following day apparently acquiesced, but later declined to go on with the operation and brought civil action for

damages against the defendant for assault and battery The jury in the lower court found that the defendant had performed an operation on the plaintiff *without his consent and rendered a verdict of $1000* against him On appeal the Supreme Court in setting aside the *verdict held* "*The conclusion we are led to is that when a person* has selected a surgeon to operate upon him and has appointed no other *person to represent him during the period of* unconsciousness that constitutes a part of such operation, the law will by implication constitute such surgeon the representative *pro hac vice* of his patient and will, within the scope to which such implication applies cast upon him the responsibility of so acting in the interest of his patient that the latter shall receive the full benefit of that professional judgment and skill to which he is legally entitled Such implication affords no license to the surgeon to operate upon a patient against his will or by *subterfuge, or to perform upon him any operation of* a sort different from that to which he had consented or that involved risks and results of a kind not contemplated As to such matters the rule in question submits nothing to the judgment of the surgeon, who as the implied representative of his patient can under such implication truly represent him only in so far as he gives to him the benefit of his professional wisdom within the general lines of the curative treatment agreed upon between them, unless, of course, a wider discretion has been accorded him Within such general lines, however, much is necessarily left to the good judgment of the operating surgeon, just how much will depend upon the circumstances of the individual case"

Physician Not an Insurer —An examination of various court opinions contained in this chapter will show that a physician in absence of con*tract to the contrary, does not personally insure against injurious* results nor for success of treatment As heretofore stated, his undertaking is to possess and exercise *the proper degree of skill and learning* and to use proper care and diligence in applying the same In 138 Mo App 231 for malpractice consisting of alleged "negligent, rash, unprofessional unskilful and ignorant *x*-ray treatment,' the plaintiff received a verdict for $3500 in the lower court The appellate court reversed the decision and remanded for new trial The plaintiff alleged that she was suffering from 'some' ailment which caused her to consult the defendant physician the defendant pronounced the ailment as hardening of the right lobe of the liver and proposed to treat the plaintiff *for the ailment with the x-rays*, that defendant so treated the plaintiff with *x* rays, that the right side of her abdomen for the space of more than a foot in diameter was blistered and became raw and sore" The court instructed the jury to determine was the *x*-ray treatment *given to* the plaintiff by the defendant in accordance with the ordinary and established practice of the medical profession for treatment of the disease *from which the plaintiff suffered*" *The defendant* had asked the court to instruct the jury "that the defendant as a physician should not be held as an *insurer of the success of treatment*

by the *x*-ray process or that it would not be attended by unexpected results; and that the defendant was only required to have the necessary learning and experience to give the treatment in a careful and prudent manner" The court refused so to instruct the jury. The Court of Appeals substantially held, "It is difficult to say whether or not the plaintiff bases the case on the charge that the *x*-rays were not the proper method of treatment for her ailment—or the charge that the defendant was negligent and unskilful in the application or both Unless the issue of fact is clearly: was the defendant negligent or unskilful in prescribing such treatment, . . instructions to the jury as requested by defendant as heretofore stated were proper and should have been given However, if that is the issue of fact, then the said instructions should have been given with additions as to the negligence and unskilfulness in prescribing such treatment at all, for a physician might be fully equipped in learning, skill and care to use the *x*-rays and yet use them in a case where a prudent physician would not have adopted them as a remedy. A physician is not to be held for an honest error of judgment. He is only required to give his patient his diligent attention and best thought and on prescribing, administering or applying treatment, to use that care, skill and prudence that an ordinarily capable doctor would use in the same or like situation and condition or circumstances The defendant is not an insurer of the success of treatment which he may prescribe" This case cited and approved in 193 Mo. App 585.

Duration of Treatment.—It is well when undertaking a treatment to consider and agree as to the extremely important feature of time. If no period of time is agreed upon to complete the services the law will imply a reasonable time, and require proof of what, in the case before it, was a reasonable time Plaintiff's witnesses as well as defendant's may testify on this It would seem best to agree for not less than a certain space of time and for a sufficient time in addition to complete the treatment of the condition existing at the expiration of that time When a physician is engaged to operate on or treat a patient without limitation of time he can cease his visits only with the consent of the patient or on giving timely notice, or when the patient no longer requires medical treatment. 48 C. J 1128 cites cases in many jurisdictions

Associates and Assistants.—A physician's assistants or associates will be held to the same degree of skill and care stated and he may be held liable for not exercising care in their selection "A physician is responsible for an injury done to a patient through the want of proper skill and care in his associate, agent, assistant or apprentice 48 C. J 1136–7. This rule will probably also hold for his nurses and technicians. "There are situations where a physician will be held liable for injury caused by no fault of his own but by the fault of another person. This liability is based upon the simplest principles of agency. A physician or surgeon may be liable for the negligence or default of

his medical assistants, nurses, or other employees or servants" 21 R C L 393 This is confined, of course, to acts done while working at or under his directions or to those acts within the scope of the agent's instructions and duties An interesting case is that of 58 N J L 193, where a physician promised the plaintiff, after examination of his wife, that he would attend her at her confinement which he stated would not be for several days He then left the city, but before his return she was confined The plaintiff telephoned the physician's house for him to come at once and in response to this message another doctor arrived who stated that he represented the first physician He proceeded and took charge of the case The child died shortly after being born, and the first physician was sued for alleged injuries to the wife resulting from the child's death The Court of Errors and Appeals held The two doctors were each of them practicing physicians, having no business connection with one another, except that one was attending the patients of the other while he was temporarily absent, even if it be admitted, therefore, that he was employed by the other to attend the wife, that did not render the other doctor liable for his neglect or want of skill in the performance of this service for a party who employs another who follows a distinct and independent occupation of his own, is not responsible for the negligent or improper acts of the other" 48 C J 1136 says due care must be exercised in making a recommendation or substitution and if he sends an agent he is liable

Compensation—"In the absence of an express agreement to the contrary the right of a physician to be compensated for his services does not depend upon the measure of his success in effecting a cure by the means employed, but upon diligent exercise under his employment, of the degree of skill as to that disease which pertains to his profession Such services are regarded as beneficial in a legal sense and the right to adequate compensation arises upon their rendition whether the outcome be in fact beneficial to the patient or otherwise 48 C J 1160 citing many cases

The fact that advice or treatment is given free or is unpaid for will not relieve the practitioner of liability He is not obliged to continue except to carry the patient beyond danger, if not paid as and when agreed and it is well if possible to have the time and amount of payment agreed, but he cannot in the absence of such an agreement without much risk, stop a treatment at a time that will expose the patient to uncertain or serious results 'The fact that a physician or surgeon renders his services gratuitously does not absolve him from the duty to use reasonable and ordinary care, skill and diligence 48 C J 1119 If a physician undertakes the treatment of a patient unable to compensate him, his liabilities for negligence or malpractice are the same as in the case of any other patient' 48 C J 1135 In 88 Iowa 320, it is said, "We can discover no good reason why the

degree of care to be used by the physician or surgeon should be less in case his services are gratuitously rendered."

In 40 Ill 209, which was an action against a surgeon for malpractice, the court instructed the jury: "That if the defendant had held himself out as a physician, he was liable for whatever damage may have occurred to the plaintiff by reason of any want of skill or care on his part whether he charged fees or not." Judgment was for the plaintiff Defendant appealed. The appellate court held "The judge stated the responsibility of a physician too strongly in his instructions to the jury It is true that a physician is liable even though he does not receive fees, but he must be held to only reasonable and not the highest degree of skill and care. By the use of the word 'any' in his instructions the judge implied that the physician was bound to use the highest skill and care" Judgment reversed. This is cited and approved in 261 Ill. App 57.

The case of 47 N Y 186 was an action against a physician for malpractice in treating the eyes of the infant plaintiff. At the trial the question was asked of the plaintiff's father: "Has the defendant ever called upon you to pay for services in that matter"? Answer, "No sir, he has never presented any bill or asked for any pay" The defendant objected to this question on the ground that it prejudiced the jury in favor of the plaintiff The trial court overruled the objection and admitted the testimony. The jury found a verdict for the plaintiff for $2000. The defendant appealed, contending that the court erred in admitting this evidence On appeal the Court of Appeals held, "Whether the physician had presented any bill or asked for any pay for services is entirely foreign to the issue. It did not legitimately prove, or tend to prove, either want of care or skill in the treatment of the plaintiff by the defendant The evidence was improper and its admission under objection error for which the judgment will be reversed"

Many physicians erroneously believe that they cannot be sued for malpractice if the treatment is carried out in a hospital or dispensary and especially if no fee is charged or if the institution collects and retains the fee We have seen that gratuitous services do not affect a physician's liability It is fairly well established in most jurisdictions that being engaged by an institution in a professional capacity, salaried or unsalaried, does not necessarily alter a physician's liability in so far as concerns negligence or skill A charitable hospital as such in the absence of a special contract to furnish proper treatment, or which has exercised due care in selecting its professional staff is not liable for the negligence or misconduct of a member of such staff during the course of his professional duties 11 C J. 377, 30 C J 466 If a dispensary patient or a patient in a charitable hospital is injured by the x-rays and it can be proved that the injury was caused by the negligent or unskilful application of the x-rays by a physician or his agent (assistant, nurse or lay technician) the physician may be liable

to pay damages There are numerous instances of this kind where a surgeon or his assistant or a nurse has left an instrument or piece of gauze in the abdomen after a surgical operation In the case of U S, 256 Fed Rep 196, *Jour Am Med Assn*, 73 1306, 1919, a visiting surgeon on the staff of a public hospital was compelled to respond in damages to the extent of $7709 for the alleged negligent treatment of deranged bones of the legs, or bow legs The patient s legs had been placed in a plaster cast by the surgeon The patient was then attended by the hospital interne It was alleged that the pressure of the cast had caused an injury that necessitated amputation of a leg There was contradictory evidence as to whether the surgeon interfered with the interne's treatment "A physician employed by a city to treat patients at the city almshouse is liable to one of such persons who is injured through the physician's negligence, although there is no contractual relation between such patient and the physician" 48 C J 1135 citing 130 N Y 325

"A hospital created and existing for purely governmental purposes and under the exclusive ownership and control of the State is not liable for injuries to a patient caused by the negligence or misconduct of its employees" 30 C J 465 "A private hospital which is run for gain is liable in damages to patients for the negligence or misconduct of its officers or employees occurring within the scope of their employment" 30 C J 465 The Supreme Court of Washington 169 Pac Rep 828 affirmed a judgment that dismissed an action brought by the plaintiff, a child to recover damages alleged to have been sustained by reason of negligence of the hospital nurses and followed its rule in a former case to the effect "a charitable institution is not liable for the negligence of a physician whom it employed but is responsible for want of ordinary care in selecting him" The Alabama Supreme Court, 191 Ala 572 68 S Rep 4 (cited and approved 226 Ala 113), however, gives a contrary opinion in a case of a hospital nurse at the same time stating that the court recognizes the weight of authority in the United States is to the contrary In the case of U S 247 Fed Rep 639, the United States Circuit Court of Appeals, Third Circuit refused to hold a charity hospital responsible for negligence and unauthorized conduct on the part of a nurse who administered poison instead of a cathartic to a patient In the case of Wyo 160 Pac Rep 385 (cited and approved in Wyo 241 Pac Rep 710) the Supreme Court in reversing a judgment obtained by the plaintiff against the defendant hospital hands down an interesting and instructive opinion The plaintiff was burned by a hot-water bottle placed in position by a nurse The court says that "two questions are presented for determination first was the hospital a charitable institution, second if so was it liable for an injury to a patient caused by the negligence of one of its nurses in the absence of allegation and proof of negligence of its officers or managers in the selection of such nurse?' The court answers the first question in the affirma-

tive, and the second in the negative, saying, "the fact that the hospital charged for the accommodation and care bestowed on the patients who were able to pay did not change its character, and that the rule is well established by legal precedents."

CLAIM AND SUIT.

It must be distinctly understood that whether there is or is not fault or want of skill on the part of the physician, he can be sued by a person claiming there are injury and damages, and the physician will be obliged to defend the suit, otherwise there will be a judgment by default taken against him Unless the matter is settled before trial he must go through a trial to submit his side of the case and depend on the court and jury to consider his contentions sufficiently made out.

Insurance —If and when one takes out insurance, read the policy. It means what it says. Do not take anything for granted It is issued on the basis of one's statements. On receipt of the first demand by or on behalf of a former or present patient made orally or in writing and whether the latter seems to be a legal paper or not, the physician should at once consult his insurance company, if he is insured for the full amount demanded If not so covered or if there is any doubt as to being covered over the entire period or if no definite amount is demanded, personal legal counsel should be seen and the insurance company should also be notified at once. In some states the county or state medical society will furnish an attorney, but it will not pay any damages Of course all other papers including letters sent one by or on behalf of the claimants should be immediately sent to one's own lawyer.

An insurance company is only liable according to the terms of the policy Actions are frequently brought for more than the amount limited in policies.

The insurance companies if liable to any extent will insist on conducting the defense, but they are not likely to object to personal counsel being associated, provided there is no difference of opinion as to the manner of conducting the defense. The company will usually make no charge for the services of its lawyers or the expenses of trial The expenses of a trial are often heavy, especially if there is an appeal

Some of the important provisions of the "physician's liability policy" of a leading insurance company are,

"In consideration of the premium herein provided for, the *Insurance Company* (herein called The Company) does hereby agree with the Assured, respecting bodily injuries, illness or death, suffered or alleged to have been suffered, by any person or persons, in consequence of any error or mistake or malpractice or alleged error or mistake or malpractice either

(b) of the assured [illegible] the assured's profession as described in Warranty [illegible]

(c) of a registered [illegible] assistant [illegible] the assured's professional instructions in the [illegible] necessarily in the presence of the assured or

(c) of an assistant of the assured named in Special Conditions who is a Licentiate [illegible] surgeon or dentist [illegible] the assured's instructions [illegible] a person similarly licensed who is the successor of an assistant so named or

(d) of any substitute of the assured engaged in the same profession and who is temporarily acting for the assured [illegible] when the assured cannot act or during a period in which the assured is not actively engaged in his professional duties as follows

To insure the assured against loss from the liability imposed by law upon the assured for damages

To give prompt and efficient service

(a) in investigating cases of bodily injuries illness or death coming within the provisions of this policy

(b) in conducting negotiations for the settlement of or in contesting any claims made on account of such cases of bodily injuries illness or death and

(c) in defending any suit brought against the assured to recover damages on account of such cases of bodily injuries illness or death unless or until the company with the consent of the assured, shall elect to effect settlement of such suit and

To pay in addition to damages all expenses incurred by the company for investigation negotiation or defense all costs taxed against the assured in any legal proceeding defended by the company, all premium charges on appeal bonds required in all such legal proceedings, and all interest accruing on any judgment for which the company is liable in whole or in part under Agreement up to the date the company shall have paid tendered or deposited in court, its share of such judgment

"Always provided that the company's liability under Agreement of this policy is and shall be limited to the amounts and in the manner expressed in Special Conditions but the company will also pay in addition all sums for which the company may be liable under Agreement—

'Provided also that this policy shall not cover in respect of bodily injuries illness or death caused or alleged to have been caused

(a) by the assured or any person acting under the assured's professional instructions or by any named assistant or successor of any such assistant or by any substitute of the assured, while in any degree whatsoever under the influence of intoxicants and the ties, or narcotics,

(b) by the assured or any person acting under the assured's professional instructions or by any named assistant or successor of any such assistant or by any substitute of the assured, in consequence of

criminal malpractice, or the violation of any law or ordinance, although the company shall not decline to defend any suit brought against the assured for damages because such suit is based on an allegation of criminal malpractice or the violation of any law or ordinance, but the company shall not be liable for any damages recovered in any such suit, or

(c) by the assured or any person acting under the assured's professional instructions or by any named assistant or successor of any such assistant or by any substitute of the assured, other than during the policy period defined in Special Condition—,

(d) by the use of any x-ray apparatus or by the use of radium unless this policy is specifically endorsed so to cover in consideration of an additional premium;

(e) by reason of the assured owning or operating any hospital, sanitarium, dispensary, clinic or other similar enterprise unless this policy is specifically endorsed so to cover in consideration of an additional premium,

(f) by reason of or resulting from the liability of others assumed by the assured under any contract or agreement oral or written

"And provided further that this policy is made and accepted subject to the General Conditions, Special Conditions and Warranties hereinafter set forth, together with such other General Conditions, Special Conditions and Warranties as may be endorsed hereon or added hereto in like manner as if the same were respectively repeated and incorporated herein and compliance with such General Conditions, Special Conditions and Warranties shall be a condition precedent to the right of recovery hereunder

"The assured, upon learning of a case of error, mistake or malpractice or alleged error, mistake or malpractice covered by this policy, shall give immediate written notice thereof, with the fullest information obtainable at the time, to the head office of the company or to its duly authorized agent The assured shall give like notice with full particulars of any claim made on account of such error, mistake or malpractice or alleged error, mistake or malpractice If any suit is brought against the assured to enforce such claim, the assured shall immediately forward to the head office of the company every summons or other process that may be served upon the assured

"The assured shall not voluntarily assume any liability nor incur any expense, nor settle any claim, except at the assured's own cost. The company shall not compromise any claim, nor settle any suit against the assured without the consent of the assured The assured shall not otherwise interfere in any negotiation for settlement nor in any legal proceeding, but whenever requested by the company, the assured shall aid in securing information and evidence and the attendance of witnesses, and shall cooperate with the company except in a pecuniary way in all matters which the company may deem necessary in the defense of any suit or in the prosecution of any appeal

"If any condition in this policy contained relating to the limitation of time for notice of cases of error, mistake or malpractice, or for any legal proceeding is at variance with any specific statutory provision of the State in which the *error, mistake or malpractice or alleged error,* mistake or malpractice occurs, such specific statutory provisions shall be substituted for such condition

'The *professional assistants of the assured, against whose errors,* mistakes or malpractices or alleged errors, mistakes or malpractices the assured is to be insured under this policy (the liability of such professional assistants is not insured under this policy) are the following (names and status to be given in full)

'The liability of the company under this policy on account of bodily injuries, illness or death of one person shall be limited to the sum of Twenty-five Thousand Dollars ($25 000) and subject to the same limit for each person the total liability of the company under this policy shall be limited to the sum of Fifty Thousand Dollars ($50,000) "

Compromise —Compromise and settlement before trial is frequently possible and often advantageous in view of newspaper notoriety, loss *of time waiting for trial or final decision because of appeal* and effect of possible adverse verdict and judgment Many have the mistaken notion that settlement concedes liability If a settlement is sufficiently advantageous it is merely a business proposition Offers of settlement should be "made without prejudice " and are not usually permissible in evidence at a trial, if such offer is not accepted

A contract of settlement is *legal,* and should be conditional to claimant giving a "general release which releases the physician from all further liability In the claims and cases of infants and incompetent persons the approval and order of the court will usually be necessary for settlement, and *in such cases effort should be made not only* to get such order, but also a "general release made by the representative of the infant or incompetent

PREPARATION FOR TRIAL

Assuming a settlement out of court to be impossible or disadvantageous, preparation for defense and trial should be made In fact steps should be taken *to those ends as soon as oral or* written demand *or claim* is made regardless of chances overtures or negotiations for settlement and to delay is hazardous Courts and juries must be furnished *proof of facts and circumstances No diligence in locating* favorable witnesses and evidence is too great Here is where the great advantage of the physician's having definite accurate data and photographic *records of the original or prior condition,* of his diagnosis treatment and results will appear He will be at a serious disadvantage without such to assist his lawyer in preparing his case and at the

trial in his testimony Such will be essential to assist his expert witnesses in forming their opinions, and giving their evidence.

The patient is apt to have a good memory for most of the circumstances which he thinks favorable to himself as it will be probably his only case of the kind, while the physician's dealing with many patients may not or only with difficulty, without data, recall exact conditions or events any one of which may be the winning point.

A complete definite bill of particulars of plaintiff's claims of injuries and damages should be obtained by agreement or order of the court as soon as possible.

It is usually advantageous to get by consent or order of the court a physical examination of the plaintiff at which examination experts, usually physicians, can obtain at first hand data of the claimed or existing condition. Usually it is best to get an examination at the start of the action and another just before trial. Some conditions complained of may justify application to court for several, even many, such examinations. This would be important if malingering were certain or suspected.

It is important to have the written medical authorities on the questions involved, and to keep in mind any letters, writings or lectures bearing on the disputed points the defendant physician may have made in the past, and at the trial also those plaintiff's expert witnesses may have made.

Expert Witnesses.—There is a saying to the effect that a lawyer is a poor lawyer for himself and for the same reason it is desirable to have as expert witnesses, one or more physicians recognized in the profession as especially qualified on the things in issue, to advise and assist in the preparation for trial and to testify, giving their knowledge or opinion of the disputed matters Experts for the respective sides often differ. They should be thoroughly conversant with such medical facts and procedure involved in the issues of the case as cannot be matters of opinion, and on which neither side can differ. They will usually differ if the inquiry extends to fields where they express an opinion outside of settled medical facts or practice It has been well said: "It is no proof of a man's understanding to be able to affirm whatever he pleases, but to be able to discern that what is true is true, and what is false is false, this is the mark and character of intelligence."

The necessity of competent expert witnesses is shown by the following cases: 123 Va 113, 96 S. E. Rep 360; *Jour. Am. Med. Assn., 72,* 1100, 1919, cited and approved in 154 Va. 381 quotes and approves, 78 Fed Rep 442, "When a case concerns a highly specialized art . . . with respect to which a layman can have no knowledge at all, the court and jury must be dependent on expert evidence. There can be no other guide, and, where want of skill or attention is not thus shown by expert evidence applied to the facts, there is no evidence of it proper to be submitted to the jury." And further quotes and approves, 23 Colo App. 163, "This does not militate against the right of the

jury to decide between conflicting testimony of different physicians or experts on the question of a standard, it only goes to the extent that if in doubt upon any matter necessary to enable the jury to say that a standard has been fixed for its guidance by the testimony of such qualified witnesses, then it cannot from other and incompetent evidence or without evidence raise a standard " This case was cited and principles approved in 154 Va 381 91 Minn 219, 97 N W Rep 882, was an action for damages for injuries alleged to have been caused by a physician's negligence and unskilfulness in the use of the roentgen rays After trial in the lower court the action was dismissed Plaintiff appealed to the Supreme Court where the ruling of the lower court was reversed *The defendant had made several roentgenograms of the* plaintiff s chest in an attempt to locate a foreign body A radiodermatitis resulted which required many months to heal, but it was healed at time of trial The alleged negligence referred to improper technic The plaintiff had an expert witness who was well acquainted with the *x* rays and their properties because of his position as professor of physics in a college This witness testified that the defendant's technic was faulty The defendant objected to this testimony on the ground that the expert witness was not a physician and was therefore incompetent to testify as to the defendant's negligence in the use of the *x* rays The defendant contended that in an action for malpractice no expert witness was competent to testify who was not a physician of the same school as the defendant *i e*, the same kind of a physician The lower court rejected the evidence given by the plaintiff's expert witness, and the case was dismissed The plaintiff appealed from this order assigning as error the dismissal and rejection of the testimony of the plaintiff s expert witness The Supreme Court on appeal held The application of the *x*-rays to the plaintiff was not for the purpose of treating a disease or ailment but for the purpose of locating if possible, a foreign substance in the plaintiff's lung, therefore the *x* rays were not in this case used as a remedial agent The *x*-rays may be applied by any person who has the requisite scientific knowledge of their properties and the court sees no reason why their application to the human body may not be explained by any person who understands them If the application of the *x* rays had been for medical purposes and not for the scientific purpose of discovering the presence of a foreign substance in his lungs it might be different Order of the lower court reversed because of error in excluding the evidence of the plaintiff's expert witness and for dismissing the action ' *The ruling of the* Supreme Court in this case would make it legal in that jurisdiction for persons other than physicians, provided they possess requisite knowledge of the *x* rays to employ the *x*-rays for the location of foreign bodies in human beings But in this case it cited and approved a previous case in that state 75 Minn 255, 77 N W 813 where it was held that in an action against a physician or surgeon for malpractice—unskilfulness in treatment being charged—

the physician was entitled to have the propriety of his treatment tested by physicians of the same school; that, if a physician of the allopathic school be sued for malpractice, the question whether his treatment was unskilful should be tested by the rules and methods of that school, and the testimony of a physician of the homeopathic school would be incompetent. The said case of 91 Minn. 219 was cited and approved in 174 Minn. 576 where it said "A doctor is only required to exercise such reasonable care and skill as is usually exercised by doctors in good standing of the same school of practice. . . . When a patient selects one of the several recognized schools of treatment he thereby adopts and accepts the kind of treatment common to that school, and the care, skill and diligence with which he is treated, when that becomes a question in the courts of this state, must be tested by the evidence of those who are trained and skilled in that particular school of treatment"

DEFENSES.

The defense or defenses should be outlined and prepared with all possible data in hand

Statute of Limitation.—The defense first in importance is the technical one of the "statute of limitations" otherwise known as "limitation of actions" or "expiration of time for suit" Such limit is usually at least one year but this varies It also depends, generally speaking, on whether the action is on contract or tort In many jurisdictions the limitation is fixed by statute In any case the choice or necessity of time and form of action must be ascertained from the law of the jurisdiction, but it is of extreme importance not only as to whether the circumstances warrant such a defense but also as to the insurance company's liability if defendant is insured. For instance, the insurance company may not cover the whole period of treatment or entire time involved in the claim.

The following are examples of how the courts have held with respect to this defense In 99 O. S. 361, 124 N. E Rep. 238; *Jour. Am. Med. Assn*, *74*, 972, 1920, the Supreme Court of Ohio, reversing a judgment of the lower court, says "the plaintiff's petition stated that, December 29, 1913, the plaintiff sustained a fracture of both bones of her left leg above the ankle-joint and on that date employed the defendant to treat the case, that he was unsuccessful in his first attempt to reduce the fracture, and in about a week attempted again to set or reset the fractured limb, and again negligently failed to place the fractured ends of the bone together . . . and treated plaintiff until May, 1914. This action for damages was begun in April, 1915. The defendant's demurrer was on the ground that the plaintiff's right of action was barred by the 'statute of limitations,' and the question was, when did the statute begin to run as against the plaintiff, did more than one year intervene between the date on which her cause of

action 'accrued' and the date on which such action was commenced'? The Supreme Court holds "this action was begun more than a year *from the date of the fracture* but less than a year *from the date the* patient was discharged In an action for a breach of contract in such *a case, the statute of limitations does not begin to run until the con*tract relation is terminated, and as under the allegations of the plaintiff s petition the *contract of employment between the surgeon and* his patient continued from December 29, 1913, to May, 1914, the plaintiff's right of action did not accrue *until May, 1914, and was not barred by* the statute of limitations when the action was brought" Cited and approved in 33 O App 165

In 181 Ia 145, 162 N W Rep 217, where action was started in 1915, fourteen years after treatment by *x*-ray and three years after development of a cancerous growth at the locality of an *x*-ray "burn" the Supreme Court affirms a judgment in favor of the defendant in that the plaintiff's alleged cause of action was barred by the statute of limitations of time to sue which for negligence was much less than that for fraud, which was five years The court says that it was alleged that in 1901 the plaintiff, then under seventeen years of age, broke his right wrist It was set by other physicians In June of that year the defendant made several *x*-ray exposures over a period of ten days for the purpose of making roentgenograms That it was alleged as a result, the skin on the hand and wrist was "discolored" that the defendant admitted that the *x* rays had caused the "discoloration" and fraudulently informed the plaintiff that the injury was of no particular consequence and would be temporary in its effects, fraudulently concealing from the plaintiff the true nature of the injury that the defendant then treated the "discoloration" for a time and it apparently disappeared, leaving a scar, but with the usual use of the hand, that the plaintiff and his parents fully relied on the *statement* and advice of the defendant as to the temporary effect of the *x*-rays and nothing further was done *in regard thereto until 1912, that the* use of the *x*-ray machine by the defendant produced a cancerous condition which was *latent and dormant until 1912 and the plaintiff had* no knowledge of said condition until then, that then the tissue of the right hand where *the x rays had been applied, broke down and became* an epithelioma or cancerous growth, which caused great pain and *necessitated amputation of the right forearm The court says* Was the plaintiff s cause of action concealed by the statement of the defendant that the *original 'burning' was but temporary and was of* no particular consequence and did the defendant fraudulently conceal *the true effect produced by the use of the x-ray machine?* The plaintiff alleged that he was 'burned' in 1901 and, as he alleged, by the negli*gence of the defendant The fact was known by* the plaintiff and his parents All damages which subsequently developed were traceable *to and based on that act By the original act* the plaintiff was injured and, as the petition alleged, by the negligence of the defendant He

would have been entitled to some damages at that time, and if it be true that cancer necessarily and in all cases is the result of such 'burning,' or if cancer is the probable result, such fact could be shown as bearing on the question of damages in an action for the original injury. If cancer is not the necessary or probable result of such 'burning,' then the defendant's statement would be more or less of an opinion and, in that case, the fact that later, and in 1912, a cancerous condition did develop and the plaintiff's damages might therefore be increased, would not constitute a new cause of action. It would seem then that the plaintiff's cause of action accrued at the time of the original injury. . . . Plaintiff's alleged cause of action is barred by the Statute of Limitations." This case is cited and its principle approved in 197 Iowa 277.

This last opinion is an important legal precedent In some cases it would seem advisable to bring out at the trial the fact that cancer is a possible but improbable late result of radiodermatitis.

No Cause of Action.—The next defense will naturally be that there is no cause of action as the physician exercised a proper degree of skill and diligence No presumption of negligence or want of skill can arise from the fact that a physician failed to effect a cure and in the absence of an agreement for specific results there can be no recovery Previous cases cited support this.

Ordinarily the burden of proof is on the plaintiff to establish the negligence or want of skill of the physician and the burden is on the defendant physician to prove his defenses

The weight of legal opinion appears to be that the existence or development of an injury or condition, after accepting a case, does not of itself establish *prima facie* negligence or want of skill. This theory has often been discussed as "*res ipsa loquitur*," or "the thing speaks for itself." "It is a term used in a limited class of negligence cases referring to the method of proof." 45 C J. 1196

Technically the plaintiff's "burden of proof" never changes But in cases where the doctrine of *res ipsa loquitur* is available to the plaintiff, proof by the plaintiff, by sufficient evidence, of the existence of the injury and damages on which the plaintiff's claim is based establishes a "prima facie case" and the defendant must, if he does not want to risk losing his case, then assume the "burden of proceeding" with evidence of facts that are in his favor to meet the "prima facie case" of the plaintiff. If defendant does so the plaintiff must again proceed to satisfy his burden of proof. Practically, the doctrine when approved by a court establishes an important presumption in favor of plaintiff and against the defendant that increases his amount of proof and difficulty of defense As is said in 45 C. J. 1221 "the fact that the doctrine is applicable to the facts of the case does not shift to defendant the burden of proving that he was not guilty of negligence, but the burden is still on plaintiff to establish the negligence of defendant, and, upon the whole evidence, he must have the preponderance

in order to succeed" 'The general rule is that, where plaintiff has established a presumptive or prima facie case of negligence by virtue of the doctrine of '*res ipsa loquitur*,' it is then incumbent upon defendant, if he wishes to avoid the effect of the doctrine, to introduce *evidence to explain, rebut, or otherwise overcome the presumption or* inference that the injury complained of was due to negligence on his part" 45 C J 1219 "Under this doctrine it has been held that an inference of negligence may be permitted in the absence of explanation by the physician or surgeon where the *thing which caused the injury* complained of was under his management or control and the accident is such as in the ordinary course of things does not happen if proper care is exercised The doctrine of *res ipsa loquitur* is not applicable where the injury is one which may occur, even *though proper care is* exercised" 48 C J 1143 'Where the thing which caused the injury complained of is shown to be under the management of defendant s servants and the accident *is such as in the ordinary course of things* does not happen if those who have its management or control use proper care, it affords reasonable evidence, in the absence of explanation by defendant, that the accident arose from want of care' 45 C J 1193

How this kind of claim arises is shown by the following examples in practice "If the maxim '*res ipsa loquitur* were applicable to a case like this, and a failure to cure were held to be evidence, however slight, of negligence on the part of the physician or surgeon causing the bad result, few would be courageous enough to practice the healing art, for they would have to assume financial liability for nearly all the ills that flesh is heir to" 78 Fed Rep 442 The latter case is cited and approved in 35 App Case 57, Dist Col , the case was tried in the Supreme Court of the District of Columbia It was an action against a physician for negligence in applying the *x*-rays for the purpose of diagnosing a fractured rib The defendant was a specialist in the use of *x*-rays for diagnostic purposes to whom the plaintiff had been sent by her own physician The plaintiff testified that she said to the defendant that she had been told the *x*-rays were dangerous and that the defendant told her that there was no more danger to her than there was to him and that she was told by the defendant's wife who was *his assistant that in a wide experience with the x rays, they* had not had an accident The defendant had several expert witnesses who testified that his apparatus and technic of application had been in accordance with good practice and as safe as such *x*-ray exposures *could be made The plaintiff asked the court to instruct the jury* that if they decided that the plaintiff was 'burned in the course of the operation that of itself would be evidence of negligence on the part of the defendant and cast on him the burden to prove that he was not negligent *The court refused to so instruct The plaintiff* appealed and court says "Generally speaking no inference of negligence can be drawn from the result of the treatment of a physician or

surgeon. . The result of the general rule is that, in an action for malpractice, the burden is always on the one alleging it, and even in exceptional cases, where a *prima facie* case is made out by proof of the operation and resultant injury, the doctrine of *res ipsa loquitur* does not relieve plaintiff of the burden imposed upon him of establishing his case by a preponderance of the evidence . . . The same rule should apply to practitioners using the *x*-rays as is applied to other practitioners" Affirmed on substantially the same reasons in Supreme Court 228 U. S. 233, which says: "In cases where the rule does apply it has not the effect of shifting the burden of proof . In our opinion *res ipsa loquitur* means that the facts of occurrence warrant the inference of negligence, not that they compel such an inference, that they furnish circumstantial evidence of negligence where direct evidence of it may be lacking, but it is evidence to be weighed, not necessarily to be accepted as sufficient; that they call for explanation or rebuttal, not necessarily that they require it; . . When all the evidence is in the question for the jury is whether the preponderance is with the plaintiff" It is said by the Appellate Court in Virginia, "The result, however bad, is of itself alone insufficient evidence to establish the unskilfulness or the negligence of a physician in such a case," 123 Va. 113–96 S E. Rep. 360, *Jour Am. Med Assn.*, 72, 1100, 1919, in affirming a judgment for plaintiff where *x*-rays had been used in treatment of eczema. Principles approved in 154 Va 381.

A case on the rule of *res ipsa loquitur*, is that in the Supreme Court of Minnesota in 134 Minn. 458, 159 N. W. Rep 1073, *Jour. Am. Med. Assn*, 68, 1938, 1917 The Supreme Court affirmed a judgment for $2500 damages in favor of the plaintiff for injuries alleged to have been caused by the negligence of the defendant, a regularly licensed physician, in taking a roentgenogram. The court said "the evidence sustained a finding that the injury was due to the *x*-rays. To recover damages it was necessary to prove negligence on the part of the defendant There was little direct evidence of negligence The plaintiff claims that during the exposure the defendant made some exclamation to the effect that the machine was not working right The plaintiff claims that the exposure was unduly long but the testimony does not strongly support such claim The plaintiff's expert witness stated that a proper application of the rays would not have produced the result he found The evidence is that with a proper machine and with a proper use of it a 'burn' is unusual. There is evidence that the machine was a proper one. The machine and its operation were wholly under the control of the defendant. Under such circumstances the rule of *res ipsa loquitur* applies It does not follow from this, as the plaintiff's counsel argues, that the burden shifted to the defendant of proving freedom from negligence *Res ipsa loquitur*, where it applies, does not convert the defendant's general issue into an affirmative defense. The *res ipsa loquitur* rule merely

permits the jury to draw an inference of negligence and the jury is to consider and weigh the inference in the light of all the facts and circumstances and give it such weight as tending to prove negligence as they deem it entitled to It does not follow from what is here said that the *res ipsa loquitur* doctrine applies to a bad result or mishap coming from a physician's treatment The rule does not apply in such cases" This statement of rule reiterated in 168 Minn 287 So instructing a jury cannot but be very advantageous to a plaintiff

A proper degree of skill and diligence is conclusively presumed by *some courts where a physician has sued and recovered for his services* As is said in a New York case, 'It must be considered as settled in this State, that a judgment in favor of a physician and surgeon for his professional services, rendered by a court of competent jurisdiction, in an action in which the defendant appeared and answered, setting up a defense which he maintained at the trial, or in an action in which he appeared and signed and filed a written confession of judgment for the amount of the services, is a bar to an action for malpractice by that *defendant against that physician and surgeon for malpractice in rendering* those services" 75 N Y 150 This case is cited in 175 N Y 229, 237, "it thus became a case in which two claims could not coexist, where if the plaintiff was entitled to have his claim allowed the defendant would be precluded from recovery" Also cited in 250 N Y 304, which says "A judgment in one action is conclusive in a later one not only as to any matters actually litigated therein but also as to any that might have been so litigated when the two causes of action have *such a measure of identity that a different judgment in the second* would destroy or impair rights or interests established by the first But it is said in 21 R C L 103 that the weight of authority is contra except when the malpractice is actually set up and litigated in the action for services"

Estoppel — A defense in the nature of an estoppel may be used where a person consults a physician as to treatment that the physician believes will be unsuccessful or will leave a deformity or disfigurement or other serious results, and he so informs the prospective patient and is nevertheless urged to give the treatment and there is no lack of skill or care on his part he should not then be held liable for the results Of course this would not excuse an operation he believes would kill the patient, nor always where it would endanger life An authority so holding as to the main proposition is 21 R C L 403 which states "If a patient is fully cognizant of the nature of the specific treatment which he is about to get, or if he actually directs a specific act, such as an operation which should not be performed it would seem that he could not properly complain later that such treatment or act constituted malpractice for which he should recover Here it would seem that he has sought to rely upon his own judgment rather than on that of the physician and can complain only if the physician negligently

performed the act or treatment that the patient ordered," citing 68 L R. A. 432, a New Hampshire case reported in 73 N. H. 46

Waiver.—"Consent of the patient to the abandonment of the case by a physician may be a defense to a subsequent action for malpractice based upon failure to give the patient the attention he required." 48 C J. 1139.

Contributory Negligence.—Contributory negligence on the part of the injured patient is one of the very important defenses. When the relationship of physician and patient is once created the patient owes a duty of care not only to the physician but to himself. As a general rule the patient will not be allowed to recover from the physician if the latter can show that the patient's negligence proximately conduced or contributed to the injury complained of. 48 C J. 1133 It is the duty of a patient to cooperate with his physician and conform to the necessary prescriptions and treatment, and follow all reasonable and proper instructions given. Therefore it is a good defense to an action for malpractice, where the physician or surgeon is charged with negligence or the nonobservance of proper care or the want of skill in performing the services undertaken, that the patient was guilty of negligence at the time which contributed to the injury complained of. 48 C. J. 1134.

Instances of contributory negligence would be where the patient fails to follow instructions, acts in a manner to prevent a recovery, adopts some different simultaneous course of treatment, fails to return for treatment, and refuses to permit proper treatment or completion of treatment. In 92 Kan. 801, an action against a physician for malpractice in the use of *x*-rays for diagnostic purposes, the defendant claimed that the damage resulted because the plaintiff failed to return for treatment of the alleged injury. The verdict was against the defendant in the lower court. The appellate court decided that "the fact that a patient discharges a physician or quits his care and employs another physician . . . is not in itself evidence of contributory negligence There was evidence that the patient had continued under the professional care of the defendant for a long time after the 'burn' was inflicted and that it grew no better but became continually worse."

Antecedent Condition.—Another defense would be that of the antecedent condition of the patient including the consideration of natural and artificial idiosyncrasies or susceptibility. This would not be in all cases a complete defense but while it might not avoid the assessment of damages it would be important in reducing them if an unfavorable prior condition can be shown Usually it cannot be employed to prove lack of negligence

Idiosyncrasy or hypersensitiveness to *x*-rays is a defense frequently employed in malpractice suits and precedents have been established. In the action 204 S W. Rep. 450 Tex., the plaintiff patient in the district court alleged negligence on the part of the defendant physician in the application of the *x*-rays in the treatment of eczema, said

alleged negligence resulting in "burning" the plaintiff The plaintiff alleged among other reasons that the *x* rays were a dangerous agent, that they had been improperly applied by the defendant, that the defendant left the room during the treatments whereas he should have remained The defendant set up as a defense that the injury of which the patient complained was caused by hypersensitiveness of the plaintiff's skin to the effect of the *x*-rays, and that he could not have discovered this idiosyncrasy prior to the treatment Although defendant produced evidence that the plaintiff's skin was hypersensitive yet the judge did not instruct the jury to take this into consideration The verdict was for the plaintiff in the sum of $2500 The defendant appealed, his main ground of appeal being the fact that the judge in the lower court refused to instruct the jury that idiosyncrasy was a defense The appellate court ruled "the defense of the defendant, *i e*, that hypersensitiveness of the skin of the plaintiff to the *x* rays was the proximate cause of the injury, was both pleaded and supported by evidence A physician is not required to take precaution against a peculiar temperament or abnormal idiosyncrasy of which he has no knowledge and for detecting which there is no means The evidence shows that the defendant did not know of the plaintiff's hypersensitiveness and that there is no way to ascertain such a peculiarity prior to treatment The testimony of the defendant's expert witnesses as well as the testimony of the plaintiff's own expert witness if credited by the jury is sufficient to authorize a finding by the jury that the plaintiff did have a hypersensitive skin and that this peculiarity was the proximate cause of the injury We think that the jury should have been instructed, that if they believed that the proximate cause of the plaintiff's injury was his abnormal hypersensitiveness but for which the injury would not have occurred, then the verdict should be for the defendant Judgment of the lower court reversed and case remanded This case was tried again and the said issues raised by the defendant were submitted to the jury which again found in favor of the plaintiff in the sum of $3500, which was sustained on appeal although the principle stated was again approved 223 S W 533

In the case of 91 Minn 219, 97 N W Rep 882, the defendant conceded that the *x*-rays frequently "burned" the body of a patient but that some persons are not susceptible to its influence while others are and that it is impossible to determine in advance who are and who are not susceptible to injurious effects On appeal the Supreme Court ruled 'that such were questions of fact for the jury to determine'

It would appear as though the question of idiosyncrasy might enter a case on both sides that it might be used both by the plaintiff and by the defendant It would be of advantage to the plaintiff if and when such a peculiarity could be detected by due care and skill There is likely to be a dispute between the expert witnesses for the defendant and those of the plaintiff relative to the possibility of idiosyncrasy and its discovery before or during treatment It rests

with the jury to decide whether or not the defendant possessed knowledge relative to the possibility of idiosyncrasy and whether or not he used due care and skill in the light of such knowledge

Mitigation.—It is always important and proper to bring to the attention of the court and jury relevant evidence bearing on matters not in themselves complete defenses because of difficulty of proof of proper skill and care or for other reasons, but tending to mitigate the damages. The agreement of a patient not to hold the physician liable, the consent to dangerous or uncertain treatment, or inducing treatment by persistent coaxing, would be examples that often could be advantageously presented. Also the negligence of the patient after negligence or want of skill by the physician, aggravation by the patient of the injury or condition, no attempt to cure or improve the same, negligence or want of skill of another doctor, improvement or entire recovery at time of the trial, and no permanent injury, are important points to be made use of in proper cases. "If any act of the patient had been shown by the evidence to have caused an aggravation of the injury, such evidence would probably have been pertinent in mitigation of damages but the mere fact of the change of physicians does not raise the presumption that damages were increased thereby" 92 Kan. 801 "If a patient should disobey the instructions of a physician and such disobedience should serve merely to enhance or aggravate the injury caused by the physician originally, then the amount of damages recoverable would be reduced" 21 R C. L. 402. In the action 49 Wash 557, the plaintiff, suffering from an "ailment of the foot," consulted the defendant who prescribed and administered x-ray treatment for the same After daily treatment for about two weeks the foot began to swell, itch and burn. Further treatment resulted in a "burn." The plaintiff alleged that the foot was permanently injured, that she would be a cripple for life and that amputation might be necessary The negligence charged was that the defendant failed properly to protect the foot from the x-rays, that he failed to discontinue the treatment when he should have done so, and improper position of the apparatus. There was testimony to the effect that there was an x-ray "burn" of the "fourth" degree and that such an injury is generally incurable There was a dispute as to whether or not the treatment and technic were correct The defendant set up as defenses, that the injury was due largely if not entirely to an ointment which spread from the affected part to other parts of the foot, because the plaintiff had used her foot contrary to instructions, that there was no x-ray "burn," that the treatment was proper, and that the foot was cured at the time of trial; furthermore the lower court instructed the jury that "if the plaintiff quit treatment before the defendant was willing that she should do so and that if any evil result came from such action on the plaintiff's part, then the plaintiff should not recover." Also, "that if the plaintiff did not follow with reasonable care and diligence, the defendant's instructions as to how she should act and

as to how she should treat and care for her foot and any injury to her foot resulted therefrom, the plaintiff should not recover" The verdict in the lower court was for the defendant The plaintiff appealed The Supreme Court held on appeal the instruction to the jury was erroneous It would be a harsh doctrine to say that if a patient by a subsequent or independent negligent act increases or augments the injury caused by a negligent or incompetent physician that then she cannot recover Such is not the law It is proper that such aggravation on the part of a patient may be shown in mitigation of damages but it does not relieve against the primary liability The court cited as supporting this opinion 86 Pa St 297 46 Ore 424 75 N Y 12, 130 N Y 325, 39 Vt 447 The court further held that if it should appear that a physician were ignorant of the effect of *x* ray exposures the jury might well conclude that the use of such a dangerous agency by one having little or no knowledge as to the probable consequences was negligence *per se* it reversed the judgment and sent the case back for a new trial In an action for damage alleged to have resulted from *x*-rays used to remove hair from the face a judge of the New York Supreme Court instructed the jury that it might in considering damages if any take into consideration the appearance of the plaintiff's face before treatment (cosmetic disfigurement of hypertrichosis) and her desire to have it removed

TRIAL

The suit will ordinarily be tried by judge and jury

The judge generally speaking rules on the law and on the admission or rejection of evidence he charges and instructs the jury on the law and may give a synopsis of the case made out by each side

If there is any doubt or dispute as to the facts in issue the case goes to the jury to decide the facts

The judge can sometimes order a new trial set aside the verdict or reduce a verdict

Either side can appeal

The appellate court may affirm or reverse the lower court, it may send the case back for a new trial only the lawyers appear in this court

In the large cities such cases often take one or more years to be reached after listing

Conclusion —Need more be said as to reliable office data and records and thorough preparation for trial?

The law is not static but there has been little if any fundamental change in malpractice law since this chapter was originally written about twenty-five years ago At that time third-degree radiodermatitis was common and so was litigation Because of modern knowledge training and technic severe acute radiodermatitis now seldom occurs But late injuries are entirely too common In most instances these late sequelæ are outlawed by the statute of limitation but not always

Because of 1945 knowledge, a jury is likely to demand 1945 judgment and skill. Suits based upon alleged injuries caused by *x*-rays or radioactive substances, unless beyond the statute of limitation, are likely to be decided in favor of the plaintiff. There still are too many such legal actions. Because of this and in spite of the large number of malpractice insurance policies now written, the premium has increased.

One must keep in mind that there is no way, except by compromise, to avoid litigation when a person, for any reason, desires to institute legal action. The best protective measures are adequate training, equipment, knowledge, judgment, and care in making statements to a patient that might be construed as an oral contract, a guarantee or even a promise of cure, or a guarantee against complications, or an undesirable result; and, finally, insurance. Every physician who employs *x*-rays or the radioactive substances should carry all the liability insurance he or she can afford.

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